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BRITISH MANUFACTURING INDUSTRIES.

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EDITED BY

G. PHILLIPS BEVAN, F.G.S.

#13

SALT, PRESERVATION OF FOOD, BREAD AND BISCUITS,
By J. J. Manley, M.A.

SUGAR REFINING,
By C. Haughton Gill (late Assist. Exam. in Chemistry, Univ. of London).

BUTTER AND CHEESE,
By Morgan Evans (late Editor of the 'Milk Journal').

BREWING, DISTILLING,
By T. A. Pooley, B.Sc., F.C.S.

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PREFACE.

THE object of this series is to bring into one focus the leading features and present position of the most important industries of the kingdom, so as to enable the general reader to comprehend the enormous development that has taken place within the last twenty or thirty years. It is evident that the great increase in education throughout the country has tended largely to foster a simultaneous interest in technical knowledge, as evinced by the spread of Art and Science Schools, Trade Museums, International Exhibitions, &c.; and this fact is borne out by a perusal of the daily papers, in which the prominence given to every improvement in trade or machinery attests the desire of the reading public to know more about these matters. Here, however, the difficulty commences, for the only means of acquiring this information are from handbooks to the various manufactures (which are usually too minute in detail for general instruction), from trade journals, and the reports of scientific societies; and to obtain and systematize these scattered details is a labour and a tax upon time and patience

which comparatively few persons care to surmount. In these volumes all these facts are gathered together and presented in as readable a form as is compatible with accuracy and a freedom from superficiality; and though they do not lay claim to being a technical guide to each industry, the names of the contributors are a sufficient guarantee that they are a reliable and standard work of reference. Great stress is laid on the progressive developments of the manufactures, and the various applications to them of the collateral arts and sciences; the history of each is truly given, while present processes and recent inventions are succinctly described.

BRITISH MANUFACTURING INDUSTRIES.

SALT.

By J. J. Manley, M.A.

Salt, one of the most important of British minerals, is known chemically as *chloride of sodium*, its two constituents being united in the proportion of thirty-six parts by weight of chlorine to twenty-four of the metal of sodium. If a piece of the latter be heated and plunged into a bottle containing chlorine, it burns vividly, unites with the chlorine in the above-mentioned proportions, and forms chloride of sodium, which may be made artificially by adding muriatic acid. Salt crystallizes in colourless transparent cubes, which are anhydrous, soluble in about three parts of cold water, and scarcely more soluble in boiling water. A saturated solution has a specific gravity of 1·205, the specific gravity of the salt being 2·125. It is inodorous, insoluble in pure alcohol, and has a purely saline taste, unmingled with bitterness, unless chloride of magnesium be present in it. At a red heat, it fuses, and becomes converted into a transparent brittle mass. The well-known crepitation which occurs when salt is thrown on the fire or otherwise strongly heated,

results from the sudden expansion of water, mechanically entangled among its particles.

Not more than twenty-five years ago, a learned (!) doctor published an elaborate treatise, to prove that salt was the "forbidden fruit," through eating which our first parents fell, and has ever since been the cause of all our diseases and ills, though only a fanatic would deny that salt serves some important and essential uses in the animal economy. The desire for salt seems an instinct implanted in the animal creation, and there is a natural craving for it, when it does not exist in sufficient quantity in food. Animals will travel long distances and brave great dangers to get at saline earths, called salt-licks; horses and cows are most healthy, when provided with lumps of rock-salt in their mangers or pastures; and even bees will sip a solution of salt with avidity. Men will barter gold for it in countries where it is scarce, and for it husbands will sell their wives, and parents their children. In some districts of Africa, salt is far more expensive than the purest white sugar in Europe, and children will suck a lump of it in preference to sweetmeats. But the existence of a greater or less appetite for salt in all individuals shows, that this substance serves more important functions than that of merely gratifying the palate. Salt being a large constituent of the human body, and forming about half the total weight of the saline matters of the blood, the constant loss of it by the secretions, the bile, and even tears, requires to be made up by the employment of chloride of sodium as a condiment. The free hydrochloric acid

found in the stomach, and which forms an essential constituent of the gastric juice, is obviously derived from the salt taken with our food; and the soda of the blood and in some of the secretions is doubtless obtained from the decomposition in the system of common salt, which is the only mineral food of man, and the only saline condiment essential to health. The motto "*Sal est Salus*" beneath the trade mark of Mr. H. E. Falk, one of the largest salt proprietors in Cheshire, says nothing but the truth.

Salt is widely distributed throughout the world. The most extensive and productive deposits of rock-salt in Europe are those of Bochnia and Wielicza, in Galicia. Numerous other deposits are found along each side of the great Carpathian range, and may be said to extend with greater or less intervals from Moldavia to Suabia, comprehending the salt-mines of Wallachia, Transylvania, Galicia, Upper Hungary, Upper Austria, Styria, Salzberg, and of Tyrol. The celebrated mines of Wielicza, in Galicia, owned by the Austrian Government, are the most beautiful, as well as the most extensive, in the world, and have been worked for more than 600 years. A large deposit of rock-salt occurs at Cardona, in the province of Catalonia, in Spain, and as it assumes the form of a rock mountain, it is worked as an open quarry. Rock-salt is found in some parts of Russia, especially in the parched and undulating steppes of the Kirghis in the south. In the steppes, also, of Asiatic Russia, lakes of salt water are numerous, Lake Inder alone containing such an abundant supply of salt of the

first quality, that it would suffice for the consumption of all the Russias, if the difficulties attending the carriage were not almost insurmountable. But of all the countries in Asia, Persia is the most abundantly supplied. All the lakes are salt, and every considerable collection of water is impregnated with it. Salt-mines also are found in different parts, and salt-deserts are a striking feature of Persian scenery. There are salt-mines in Morocco, but the product is of a red colour, very strong and coarse. The lakes of Barbary are almost all as salt as the sea, and in the course of the summer many dry up entirely, leaving the mineral incrusted on their beds; and near the lake of Marks, in the Algerine territory, is a mountain composed entirely of salt. Salt-water lakes abound also in Southern Africa. In the United States, numerous springs indicate large deposits of rock-salt, which is also found in various parts of the southern continent of America.

The manufacture of salt in the United Kingdom is a very important industry, though the salt-producing area is comparatively small, and mainly confined to two districts, in Cheshire and Worcestershire. Salt was produced from the brine-springs in these districts at a very early period of our history, and it would seem that all places where such springs or brine-pits existed, were called by the name of *Wich*, a termination that still distinguishes most of the salt towns at the present time. The name Droitwich, it seems, was originally *Wich*, and it is supposed that the prefix *Droit* was given to designate a certain legal or allowed

brine-pit. Some of the earliest records of the brine-springs relate to those of Droitwich. It appears that in the year 816, Kenulph, King of the Mercians, gave Hamilton and ten houses in Wich, with salt-furnaces, to the church of Worcester; and about 906, Edwy, King of England, endowed the same church with Fepstone and five salt-furnaces, or scales. William the Conqueror caused an inquiry to be made into the names of the several places, and by whom they had been held in the time of Edward the Confessor, and found the Wiches and salt-houses then in operation recorded. Henry III. caused the brine-springs to be destroyed, to prevent the Welsh, with whom he was at war, from getting supplies of salt. Later on there were 216 salt-houses at Nantwich. In 1671 it appears that at Winsford two salt-works were in operation, and in 1808 Dr. Holland described the brine-springs of Cheshire. In Staffordshire, at Shirleywich and Weston-upon-Trent, brine has been used from early times, as also in Somersetshire, Westmoreland, Durham, Lancashire, and Yorkshire; but these latter were either weak, like those occasionally met with in coal-mines, or were situated where fuel was scarce, so that they have not been much noticed. In Ireland, at the west side of Eden, near Carrickfergus, there is an old hole where water enters, which is called the "salt-hole," but how it got that name, or whether there has been any ancient working of brine, appears to be unknown. Cheshire is now the great seat of the salt trade, but the salt district in that county is confined to the basin of the river Weaver, and chiefly to the locality between Winsford

Bridge and Winnington, though in the valley of the Wheelock, a tributary of the Weaver, in the neighbourhood of Sandbach and Middlewich, it is also manufactured.

Salt is obtained either in a solid state from *Rock-salt* mines, or from the evaporation of the water from the brine-pits or springs; and though the latter have been worked from the earliest periods in the history of this country, part of the pay of the Roman soldiers being in salt, giving rise to the word *salarium*, "salary," the deposits of fossil or rock salt were not discovered till the year 1670, when in the process of searching for coal in Marbury, about a mile to the north of Northwich, a stratum of rock-salt was hit upon, about 30 yards thick and about 34 yards below the surface of the ground. In 1779 rock-salt was discovered near Lawton in three strata, with beds of indurated clay between them, the lowest stratum producing the purest salt. In 1781 the owners of the Marston Mine at Northwich instituted lower sinkings, which resulted in what is now known as the "bottom of the bed" of rock-salt. The old shaft by which the bottom bed was thus proved still remains, and the workings that were made from it in the bottom bed still form a part of the present Marston Mine; but the work in the bottom mine has long been carried on by shafts sunk direct from the surface. The depth to the floor of the bottom bed is 110 yards at Northwich, and at Winsford, a few miles distant, 159 yards. The two beds of rock-salt in the Marston Mine are each from 28 to 30 yards in thickness. Further explorations show that more rock-salt lies below what is called the bottom

bed, but it is in thin strata and irregular spheroidal masses or lumps, none of which have yet been worked. In Worcestershire some of the brine-pits at Droitwich have pierced rock-salt, and at Stoke Prior, in the year 1829, a rock-salt pit was sunk and partially worked. In Ireland rock-salt was discovered at Duncrue, near Carrickfergus, in 1851, and worked since that time. In Yorkshire also, in the year 1863, at Middlesbrough on Tees, rock-salt was found in a bore-hole that was being put down for fresh water, at a depth of 431 yards. The sites of most, if not the whole, of the old rock-salt pits appear to be known, and about forty old workings are now closed. The rock-salt pits now open in the United Kingdom are about twenty-five, of which seven are at Marston and six at Winsford. It is evident that rock-salt was formed in remote ages by saline deposits from the tides, which left salt water to be evaporated; and so thoroughly free from all moisture have these deposits become, that chemical analysis proves that there is absolutely no water at all contained in them, while one or two parts out of every hundred are found in the driest salt made from brine.

A winning, as it is called, for working *Rock-salt* as now sunk, consists of two shafts, placed from 10 to 15 yards apart, with another for pumping the surface water, which is sunk only as deep as the water penetrates. A few of the winding shafts are made wide enough for two ropes, and are fitted with conductors; but most of them, at the part which is cased to keep back the fresh water and brine, are only about 3½ feet in diameter, and as the buckets used for drawing with

are nearly as wide, they rub against the sides. One of the earliest precautions found requisite in the rock-salt shafts, and afterwards in brine-shafts when they came to be sunk through rock-salt, was the necessity for protecting the rock-salt at the sides from being dissolved by fresh water. Consequently, all shafts going from the surface into rock-salt are turreted or roofed over to keep out rain and snow, and are carefully cased down to a solid foundation, below where surface water penetrates into the ground. In olden times the casing seems to have been made of wood, but recently this has been substituted by iron. Cast-iron tubing for the shaft casing was introduced into the rock-salt mines of Northwich by Mr. Arthur Anderson, senior, about the year 1845. The construction of it is similar to what had long been used in colliery shafts, when it was originally cast in complete cylinders, instead of segments, as introduced by the late Mr. John Buddle. These improved cylinders were at first made plain at the top, and left rough as they were cast, but now they have a ledge at the back to keep the column straight, and the faces are turned in a lathe to make them fit well. Wood slips have usually been placed between each cylinder to make a close joint, but latterly indiarubber rings, 1½ inch broad and ⅜ inch in thickness, have been substituted, and so far they are found to answer well. The space behind the cylinders is filled with cement to make all as close as possible. It was supposed that what the wood casing failed to do, would be effectually accomplished by these iron cylinders, and in most instances, when they have been properly secured

through the top bed of rock-salt and properly based at the bottom, this has been effected. However, notwithstanding the greatest care in putting in the castings, fresh water sometimes finds a passage behind them, which, if not discovered and speedily stopped, soon dissolves the rock-salt, so that the wedging ring and cylinders slip and the shaft collapses. In the present bottom-bed workings, the height of rock-salt varies from 15 to 18 feet in Cheshire, and from 30 to 40 feet at Carrickfergus. The mode of working the mines in both districts is to drive out in the upper part about 5 feet 9 inches high, which is called the "roofing," and to follow up with the "benching," leaving pillars of rock-salt where they are required. In driving the roofing, a little holing and cutting has to be done, but as much as possible is blown out with powder, after which the roof is dressed off with the pick. The benching varies from 9 feet 3 inches to 12 feet 3 inches in thickness in Cheshire, and from 24 feet 3 inches to 34 feet 3 inches in Ireland, which is blown off by a succession of shots in a slanting direction from the top to the bottom.

The greatest number of men down one pair of shafts is about eighty, and the quantity of powder used by that number is 1 cwt. a day. The drills used for drilling the shot-holes are about 8 feet in length, pointed at each end, and larger in diameter in the middle, for handling, no hammer being used. In charging the shot, the fine rock-salt made in drilling the hole is put next the powder, and the coarser grained upon that. The stemmers are made of iron, and so are the prickers, which weigh two or three

pounds each. Safety fuse is very seldom used. The charge is fired by a straw filled with fine powder, which is lighted up by a piece of candle-wick. In firing the shots, the men retire only a few yards, but as the rock-salt does not usually fly far from the shots, and as it will not strike a light either with iron or steel, accidents with powder are much fewer than might be supposed. The winding is now done entirely by steam engines; and iron tramroads are used, though instead of sleepers, the rails are often fixed to pegs let into drill-holes in the rock-salt. The two winding shafts are open to each other in the same chamber at the bottom, without any separation for ventilation, as practised in other mines. The ventilation, notwithstanding the smallness of the shafts, and the want of ventilating power and partitions for sending the air round the workings, is usually good, except for about two months in the hottest part of the summer. At that time the air, it appears, becomes stagnant, and it is said that the miners, when they used to stay in it, got headaches, and their clothes smelled of stale powder smoke. This continues until the cold weather sets in, when the pits again begin to draw freely, and the bad air, as it comes out, may be inhaled in the adjoining lanes. In a general way, the rock-salt strata are remarkably free from carbonic acid gas, and in only one instance at Northwich, and another at Meadow Bank, Winsford, does fire-damp appear to have been met with, and even then in very small quantity. The workmen look healthy; and as a proof of the usual purity and coolness of the air, butcher's meat will keep good in the mine for weeks even in the hottest time in summer.

About 230 miners are employed below ground at Northwich, and 36 at Winsford, besides some 20 men called "ferryers," who assist when rock-salt is being sent out. At most of the mines, women are employed on the surface to pick refuse. The system of working the mines appears to have varied very little since the beginning, but the size of the pillars and distances between them has been a moot point. An old plan, dated 1786, is in existence at Marston, showing the top and bottom workings of the Marston Mine, as they existed at that time. The size of the pillars in the top bed is about 6 yards by 4, and in the bottom bed (which was then only being commenced) the shaft pillars were set out from 10 to 12 yards in width. The workings in the bottom bed at the Marston Mine are now the most extensive in Cheshire. They are in an oval form, 640 yards long by 820 broad, extending over about 36 statute acres. There are altogether 131 pillars in the mine. The height of each pillar is about 5 yards, and they are of various breadths, lengths, and distances apart. Several are 8 or 9 yards square and 25 yards apart, which seems scarcely sufficient, as some of these are cracked at the corners. The present ones are 10 yards square, and 25 yards apart. The thickness of the strata which they have to support from the base to the surface, is about 110 yards. At Mr. Dalway's mine, on the dip of the Duncrue Mine, at a depth of 295 yards, which at present is the deepest mine in the United Kingdom, and where 40 feet of rock-salt is being worked, the pillars are 12 yards by 10 at the top, widening to 14 yards by 12 at the bottom. This and Duncrue Mine are both

new; and it remains to be proved, how the roof will stand with this height of working and consequent reduced thickness of rock-salt left for the roof. The greatest distance now to be seen of the roof of any rock-salt, standing without intermediate support, is the 43 yards in Platt's Hill Mine. The utmost span to which it would stand, will probably depend upon the thickness and strength of the roof, varying upon the same principle as with beams. It would appear that at 110 yards from the surface, with a thickness of 22 yards of rock-salt left above the pillars, a width of 25 yards is found to stand secure, and the proportion of 10 yards by 10, equal to 100 square yards for each pillar left in each area of 35 yards by 35, equal to 1225 square yards (being in the proportion of one of pillar to every 12¼ excavated), is usually found enough to stand without crushing. Pillars, 8 yards square and 25 apart, being in proportion of only about one part left for each 17 parts excavated, have been found to stand, where the workings are narrow and the roof derives support from the boundary ribs; but for a large area of workings, this proportion seems inadequate. Crushing begins usually by cracks or breaks at the corners of the pillars. Even in this state the salt generally adheres together, but the roof "creeps" nearer the floor, and the parts of the shafts which are in rock-salt become smaller in diameter. In three mines worked about thirty-five years ago, the roof of the bottom bed did not adhere, but fell in. When the working of rock-salt in Cheshire became extended to the bottom bed, and the top bed was discontinued, the pillars in the bottom workings seem

to have been made without regard to placing them under those in the top workings.

In the year 1872 the Japanese ambassadors and their suite, accompanied by several leading members of the Salt Chamber of Commerce, paid a visit to the Marston Mine. The occasion was most interesting, and the ambassadors, in a document to which was appended their signatures, expressed themselves highly delighted at what they had seen and learnt. Occasionally as many as a thousand persons from Manchester and other manufacturing centres make an excursion to the salt district of Cheshire and descend a mine, thoroughly illuminated for the occasion, long "streets" being fitted up with stalls and refreshment bars. Music is also plentifully supplied, and as many as 400 persons have been known to join in one dance in these crystal halls.

The "pits" from which the *Brine* is obtained for the manufacture of white salt by evaporation are of two kinds, namely, the "springs," which come from the top of the rock-salt, or, as it is locally termed, the "rock-head," and old rock-salt mines which have become inundated, and in which the water is consequently saturated. It is quite impossible to obtain any list of the ancient brine-pits ever discovered, but of known brine-pits now closed there are over seventy, perhaps even one hundred, in the United Kingdom. The number of those at present worked, including "rock-head" brine and old rock-salt pits, is over fifty. In Camden's time, the method of raising the brine was by human labour. He says, "At Northwich there is a deep and *plentiful brine-pit,* with stairs about it, by which, when

the people have drawn the water in their leathern buckets, they ascend half-naked to these troughs and fill them, from whence it is conveyed to the wich-houses." Hand-pumps were afterwards used, and in a few situations which admitted of the assistance of a stream of water, a water-wheel was employed; then horse power and afterwards windmills were introduced; but subsequently steam power superseded all other methods, as the demand for salt increased. The pumping is done through shafts, in the sinking and securing of which the precautions requisite are identical to those required in the rock-salt pits, and having been earlier in point of time, the necessities appear to have been met as they arose. It seems that in sinking to many of the springs, the supply of brine when cut into was so copious, that the sinkers had to escape for their lives, sometimes rising up the shaft amongst the brine without any opportunity being afforded of seeing what was underneath; a fact which accounts for the lateness of the discovery of the rock-salt. In those sinkings where it is still unknown at what depth the brine is likely to be met with, there seems to be no entire remedy against these sudden irruptions. But in the "proved" districts, it is now observed that before reaching the top of the rock-salt, when the rock-head brine flows, there is often a bed of hard marlstone called "the flag," and that for a few feet above it the marl is of a granular structure called "horsebeans." Therefore, when these indications are observed, and the brine is expected to be found at a high pressure, the practice is to case the shaft sides carefully down to the flag, to keep the sides secure and prevent

surface water from entering. The flag is then either blown through with powder, or bored through with boring rods. One of the best methods of tapping the brine, when under pressure, is to sink the shaft nearly as deep as to where the brine is expected, and then to case it with iron cylinders, having an iron bottom to the lowest, with two holes in it for pipes to be attached. From each of these holes a column of pipes of about 4 inches in diameter is erected inside the cylinders, either at the top, or as high as the brine is expected to rise; the bottom pipe having holes in it to let out the brine when it is tapped. Being thus equipped, a set of boring rods is let down each pipe, and the remaining strata between the bottom of the cylinders are bored through into the brine, which rises up the bore-hole, and passes into the cylindered shaft, wherein it rises to its level, and although the bottom of the shaft may never again be seen, the bore-rods may at any time be used through the pipes, either for removing obstructions or deepening the holes. Provision is also sometimes made for having a plug or a tap at the bottom, so that, if needed, the entry of brine into the shaft may be stopped and the shaft emptied. In the brine-shafts, when brine is pumped out of the old rock-salt mines and is met with at a much higher pressure than in the rock-head brine-shafts, the tapping has been attended with extraordinary difficulties. The brine in these old workings rises to as high a level as the rock-head brine; and as it has to be tapped through a pillar at the bottom of the old workings, the pressure is proportionately higher. The depth from the *surface* at which the brine-springs are found,

the level they take when the stratum which immediately confines them is penetrated, and the abundance of the springs are very various. In Cheshire, in 1808, according to Dr. Holland, the brine at Nantwich was met with about 10 or 12 yards from the surface, and it was difficult to avoid brine in sinkings for fresh water. The brine when reached rose nearly to the surface. At Winsford, it was about 55 to 60 yards before it was met with, and when found it was in great abundance, and it rose to within 12 yards from the surface. At Northwich, it was likewise very abundant, and was found at from 30 to 40 yards. At Middlewich, the springs were not fluent, and occasionally were pumped dry. The depth varied from 35 to 84 yards. At the present time, in Cheshire, no brine is worked at Nantwich, or at any place higher up the Weaver. It still flows to the surface in a weak state below Audlem, and at Brine Pits Farm, and at Shrewbridge and Beambridge about a mile from Nantwich. At Winsford, it is met with at the same depth as before, and is still very copious, but the pumping being greatly increased, it now only rises to between 39 and 46 yards from the surface, except on Sundays, when the pumping in many shafts is stopped. The average level is being lowered at the rate of about 1 foot annually; when it is at the lowest, some of the shafts are dry. At Northwich, the depth where it is now met is about 44 yards below the canal level, and it is kept down by pumping to nearly that depth. At Anderton, it is now found at 78 yards, being about 70 yards below the canal level, which varies between 48 and 64 yards. At Malkin's Bank, the pits are now

75 and 77 yards, and bored to 80 yards; the brine stands at 63 yards when the pumps are at work, but rises 2 feet higher when they have been standing twenty-four hours. At Wheelock, the deepest shaft is 88 yards, and bored 6 yards below that, and the level to which the brine rises is between 30 and 35 yards from the surface. At Middlewich, the deepest pit is now 90 yards. The level which the brine takes in some of the pits varies between 25 and 70 yards from the surface. A daily record has been kept by Mr. H. E. Falk, of the Meadowbank Spring at Winsford, which shows that at the beginning of each week, when most of the pumping has been stopped, the level is higher. In Staffordshire, the brine at Shirleywich in 1808 appears to have been abundant, but weak, and it is still apparently the same. The level to which the brine rises, when not kept down by pumping, is 12 yards from the surface. In Worcestershire, at Droitwich, the brine is still copious and strong, and when it is not kept down by pumping, it rises to the surface. The Droitwich Salt Company's shafts are 26 yards 2 feet, and bored to 70 yards. At Stoke Prior, with the present pumping, the brine rises to 65 yards from the surface, and it is not apparently lowered by pumping, but access may be had to the bottom of the shafts by plugging the bore-holes. These shafts belong to Mr. Corbett, M.P.; two of them are 96 yards, and bored to 117 yards; one of them is 85 yards, and bored to 117; the fourth, 96, and bored to 121 yards.

It may here be well to say a few words on the *Analyses* of *Brine* and *Rock-Salt.*

It seems to have been long noticed that in Cheshire the Northwich brine contained a trace of iron, and that the earthy salts were the same which were held in solution by sea water, being principally chlorided magnesia and sulphate of lime; the proportions of earthy salts to pure chloride of sodium in sea water being greater than that which prevailed in the brine. The analyses given by Dr. Holland in 1808 show that the percentage of chloride of sodium and of earthy salts varied in the following proportions in one pint:

	Oz.	dr.		Per cent.			Per cent.	
Winsford brine	6	1,	or	25·312	of salt,	and	2·500	earthy salts.
Leftwich ..	4	15	„	21·250	„		·625	„
Northwich ..	6	1	„	25·312	„		1·562	„
Witton	5	7	„	23·125	„		1·562	„
Anderton ..	6	6	„	26·566	„		1·875	„
Wheelock ..	6	0	„	25·000	„		·625	„
Middlewich ..	6	2	„	25·625	„		·625	„

The brine used in the manufacture of white salt is nearly "*saturated*," i. e. contains as much salt in solution as water is capable of holding. *Fully* saturated brine contains in every 100 lb. about 27 lb. of salt. The best Cheshire brine contains from 25 lb. to 26 lb. per 100 lb. If a brine contains one-fourth of its weight of salt, it is very satisfactory. It is usual amongst manufacturers to estimate the strength of brine by the weight of salt in a gallon; 2 lb. 8 oz. being considered good, and 2 lb. 10 oz. very good. Occasionally it is met with, yielding only 2 lb. 4 oz. to the gallon. The importance of strong brine in salt manufacture is evident, when we consider that all the excess of

water above saturation point must be evaporated. The excess in cost of making a ton of salt out of 2 lb. 4 oz. brine, as compared with that out of 2 lb. 8 oz. brine, may at the present time be stated at *9d.* per ton; and consequently if competition should be very severe, this would practically shut out the maker with weak brine from the market.

Recent analyses of Cheshire and Worcestershire brine, extracted from Richardson and Watts, 'Chemistry as applied to Arts and Manufactures,' vol. i., part 3, and an analysis of the crushed Marston rock-salt made for Messrs. Fletcher and Rigby, by Professor Crace Calvert, dated 25th August, 1871, are as follows:

Constituents in 100 Parts Brine.	Cheshire.		Worcestershire.	
	Marston.	Wheelock.	Droitwich.	Stoke.
Chloride of sodium ..	25·222	25·333	22·452	25·492
Chloride of potassium	..	..	..	..
Bromide of sodium ..	·011	·020	trace	trace
Iodide of sodium ..	trace	trace	trace	trace
Chloride of magnesium	..	·171	..	..
Sulphate of potash ..	trace	trace	trace	trace
Sulphate of soda ..	·146	..	·390	·594
Sulphate of magnesia	..	..	..	..
Sulphate of lime	·391	·418	·387	·261
Carbonate of soda ..	·036	..	·115	·016
Carbonate of magnesia	·107	·107	·034	·034
Carbonate of manganese	trace	trace	..	..
Carbonate of lime ..	trace	trace	trace	trace
Phosphate of lime ..	trace	trace	trace	trace
Phosphate of ferric oxide	trace	trace	trace	trace
Alumina	trace	trace	..	..
Silica	..	..	trace	trace
	25·913	26·049	23·378	26·397

Another table of direct results of analyses calculated in 100 parts, is as follows:

	Droitwich Brine.			Stoke Brine.		
	I.	II.	Mean.	I.	II.	Mean.
Potassa	..	..	trace	..	..	trace
Soda	12·1501	12·1217	12·1359	13·7804	13·7754	13·7779
Lime	·1581	·1612	·1596	·1102	·1049	·1075
Magnesia	·0167	·0159	·0163	·0187	·0143	·0165
Sesquioxide of iron	..	..	trace	..	..	trace
Chlorine	13·6167	13·6329	13·6248	15·4479	15·4916	15·4697
Bromine	..	..	trace	..	..	trace
Sulphuric acid ..	·4886	·4876	·4881	·4896	·4880	·4888
Phosphoric acid ..	..	..	trace	..	..	trace
Silicic acid	..	..	trace	..	..	trace
Residue on direct evaporation ..	23·4205	23·4205	23·4205	26·4632	26·4866	26·4749

The following table in round figures will show the relative strength of some English, compared with some foreign, brines:

	Per cent.
Northwich	25
Winsford	25
Droitwich	25
Lüneberg	25
Schöneback	8 to 11
Fredericshall	20
Rottenmünster	26
Château Salins	14
Arc	3 to 8
Dieuze	14
Onondaga	14 to 18
Goderich	26
Moutiers	2

Dr. Holland's analyses of *Rock-Salt* also show that the transparent portion which is found in small quantities is almost pure chloride of sodium, and has

no admixture of earth or earthy salts, or any combination of chloride of lime or magnesia; and that the less transparent portions consisted of chloride of sodium, with a certain proportion of earth or common clay, varying from one to thirty per cent. In each 480 grains it was found, that some of the specimens contained a few grains of sulphate of lime, and that the quantity of pure rock-salt which can be held in solution by a given quantity of water was 6 oz. of salt to 16 oz. of water. The following may be taken as the constituent parts of Marston rock-salt:

Chloride of sodium	96·70
Chloride of calcium	·68
Sulphate of lime	·25
Potassium	trace
Magnesium	trace
Water	·63
Insoluble matter	1·74
	100·00

But the constituent parts of rock-salt vary so considerably with the portion of the beds from which it is taken, that it is likely that the percentage of earthy matters found in the different brines will vary with that of the rock-salt from which it is formed. If the same spring were at all times formed from solution of rock-salt of the same purity, some conclusion might be drawn as to the identity of the respective springs; but the constant lowering of the rock-head, by which layer after layer containing different portions of earthy matter are in turn dissolved, preclude much, if any,

reliance being placed in this respect; and the same may be said with regard to the strength, which is affected by the quantity of fresh water finding access to it, either through the sides of the shaft where it is pumped, or through the surface of the earth, and by other circumstances. One of these other ways, as Dr. Holland pointed out, is the extent of the surface of the rock-salt exposed to the water. If the brine be pumped up seldom, it is found to be weaker than it would be if it were drawn up more frequently, as the water on the stratum of rock-salt remains almost at rest till put in motion; whilst by raising the brine when in this state, the portion of it which is immediately in contact with the rock-salt becomes saturated. Acquiring, however, at the same time a greater degree of specific gravity than it had as pure water, it prevents the water above from sinking down so as to act upon the rock-salt, and the sum of solution is consequently less, than when the pit is frequently worked and the rock-salt exposed to a more constant action of the water.

I now pass on to the manufacture of table salt, by evaporating by artificial means the brine raised from the brine-springs. In the time of Edward the Confessor, brine-pits, as previously noticed, were wrought at all the *wiches* in Cheshire; but at that period, and for several centuries later, the art of making salt seems to have been very imperfectly understood, and the quantity was inconsiderable. Henry VI., being informed that a new and more productive method had been invented in the Low Countries, invited John de Sheidame, a gentleman of Zetland, with sixty persons

in his company,[3] to come and instruct his subjects, promising them protection and encouragement. The result is not stated; but it does not seem to have been successful, for we find the Royal Society, soon after its institution, directing its attention to the improvement of the art of manufacturing white salt, and publishing several new methods, or rather, reports of the methods then in use, than suggestions or improvements. The salt made in England was still considered inferior to foreign salt; and that which was manufactured in Cheshire, was confined to the supply of its own consumption and that of a few neighbouring counties. About the commencement of the last century, the attention of the House of Commons was directed to the supposed inferiority of the English manufacture; and a reward was granted to Mr. Lowndes, a Cheshire gentleman, for certain improvements made by him. In 1748, Dr. Brownrigg published a treatise on the 'Art of Making Common Salt.' Some of these improvements were adopted with good effect, and others engrafted on them. The river Weaver was also made navigable for vessels of considerable burthen from Northwich and Winsford to Liverpool, whereby the facilities for distributing Cheshire salt became greatly increased; the manufacture gradually rose into importance, and salt was not only distributed over the country from this source, but considerable quantities were exported.

The process is on the whole very simple; and though many attempts have been made to introduce more scientific methods, and numerous patents have from

time to time been taken out for this end, the long-established plan of evaporating the water from the brine in large shallow pans by means of heat applied below them is still in vogue; nor does it seem likely that it will be superseded. The brine, on being pumped from the pits, is run into large cisterns, or into reservoirs made sufficiently high for it to flow by gravitation through pipes, as it is required, into the evaporating pans. It is then evaporated upon one general principle. The heat is usually supplied from coal fires underneath, but sometimes the spare heat from a steam-boiler or the discharged steam from an engine is used; and occasionally there are pipes with steam in them, amongst the brine in the pans. In this way, according to the degrees of heat, the product is small or large grained salt; the simple rule being, that the greater the heat employed and the less time in the pan, the finer the salt made, while the less heat and the longer the time in the pan, the coarser the salt. For what is called "lumped," or fine-grained, the brine in the pan is brought to a temperature of 226° F., which is the boiling point for brine. Crystals soon form on the surface, and after skimming about a little, they subside to the bottom. Each crystal appears granular or a little flaky, and is in the form of a small quadrangular, though irregular, pyramid. For common salt the temperature is 160° to 170°. The salt thus formed is close in texture, and clustered together in larger or smaller pyramids according to the heat applied. For large-grained flaky salt the temperature is 130° to 140°; for large-grained fishing

salt, 100° to 110°, the slowness of the evaporation allowing the salt to form in cubical crystals, although it appears that they are not perfect cubes. What used to be called "bay-salt," or salt formed by the operation of the air and heat of the sun, seems now to be a thing of the past, so far at least as the salt districts are concerned, although varieties are manufactured to suit the fancy of purchasers. To produce these kinds, foreign matter supposed to be of a harmless kind, such as the white of eggs, calves' and cows' feet, ale, flour, resin, butter, alum, &c., have been added to the brine for clarifying and to promote crystallization. The finest salts are drawn from the pans twice or three times in the twenty-four hours. If allowed to remain too long, the salt crystals would increase in size, and the thick layer of salt on the bottom of the pan would prevent the heat reaching the brine sufficiently to keep it boiling. For "drawing" the salt, it is brought to the side of the pan by a scraper or rake, and then taken out by a long, flat, perforated iron instrument; for it must be remembered that the brine, as fast as it evaporates, is replaced by more, so that the pan is always nearly full, and thus it is necessary to let the brine drain out of the salt. Fine salt, as taken wet from the pans, is generally put into "tubs" or moulds which are placed at the edge of the pans, their shape being that of the lumps of salt seen in our shop windows. Eight of these tubs of 14 lb. each make the cwt. It remains in them till the water drains off and it attains consistency enough to be handled, which is the case in about half an hour. It is then turned out and carried

into the stove which is at the back of the pan, and is formed by continuing the flues and bricking them over, having the chimney at the far end. The lumps remain till perfectly dried through (known by their giving a clear ringing sound when struck), and then go to a store room above the stove, which receives heat from it. The lumps are then ready either for sending out as stoved lumps for household and other purposes, or for breaking up and filling into sacks for exportation, especially for America, for which country it is often ground finer in mills before being packed. Sometimes the fine salt is not stoved at all, nor yet made into lumps, and is then generally known as butter salt. The largest kind of salt is sometimes allowed nearly a fortnight for formation in the pans. The natural form of the crystals is a perfect cube, unless the formation is interrupted by agitation or strong heat. These cubes exhibit diagonal striæ, and frequently on each side produce squares parallel to the external surface. Every cube is formed of six quadrangular hollow pyramids joined by their apices and external surface, and each of these pyramids is filled up by others, similar, but gradually decreasing. By a due degree of evaporation, it is not a difficult matter to obtain these pyramids distinct and separate, or six of such, either hollow or more or less solid, joined together round a centre. Their bases and altitudes are in general equal (thus showing the disposition of salt to form a cube), and they are composed of four triangles, each formed of threads parallel to the base. These threads are a series of small cubes. The crystals of salt, formed

by natural evaporation of brine from a pool on the floor of a rock-salt mine, are in cubes about half an inch in size, which lie in various positions; but where salt is formed in a rock-salt mine by evaporation of brine trickling through the air, it is in an efflorescent form. The earthy matter contained in the brine is got rid of in the manufacture by its adhering to the pans in the form of scale, called "pan-scale," or "pan-scratch." There is also the chloride of magnesium, called "bittern," which remains in solution after the chloride of sodium (or common salt) is formed. This is often purposely allowed to flow away by having the floor, or the "hurdles," on which the salt is lifted from the pans, lower than the top of the pan. The pans are of various sizes, the only limitation being, that they must not be too wide for a man to draw out the salt with a ladle. Old records show that they were formerly made, at least in Northwich, of lead, but now commonly of wrought iron, three-eighths of an inch in thickness, and about 50 or 60 feet in length, by 24 or 25 feet in breadth and 2 feet in depth; but some of the new pans are 140 feet by 30 feet by 2 feet. Indeed, they seem to have been gradually increasing in size. In the year 1648, they were less than 3 feet square, and even then it appears they had been lately doubled.

The salt-producing area in Worcestershire is very much smaller in extent than that in Cheshire, and the locality of manufacture is confined to Droitwich and Stoke Prior, a rural parish between that town and Bromsgrove. Beds of rock-salt underlie this district,

and the brine-springs from which the salt is made are simply springs of water saturated, or very nearly so, with salt from the rock. At Droitwich, which is the original seat of the salt manufacture, these springs used to rise to the surface, the name of the settlement in Roman times, "*Salinæ*," pointing to this fact. The subterranean resources, however, having been drawn upon through a long series of years, the brine has become more difficult to obtain, and at present is reached by shafts (lined with iron cylinders to prevent the entry of fresh water) from 80 feet to 100 feet deep, in which it rises to within about 30 feet of the surface. The salt manufacture in this district is almost entirely monopolized by the Droitwich Salt Company, and Mr. John Corbett, M.P., at Stoke Prior. His works are among the largest in England, and are certainly the most complete of their kind, covering an area of no less than 22 acres. Here the brine is pumped from wells varying from 300 feet to 800 feet deep, an increase of depth as compared with Droitwich, which is rather to be attributed to the conformation of the surface of the ground than to any difference in the position of the salt-bearing strata. The full weekly production at the two establishments would be about 6000 tons, if always at full work, and the three kinds of salt chiefly made are "butter," "table," and "broad" salt, the latter being largely used for agricultural purposes. Mr. Corbett is the patentee of a new mode of preparing salt of a superior fineness and hardness, which consists in the use of a covered pan, inside which a number of rakes are made

to revolve by steam power. The agitation of the brine and the greater heat caused by the retention of the steam combine to produce a more rapid deposition of the salt, the crystals of which are consequently very fine and hard. Mr. Corbett has also provided model cottages at a moderate rent for his workpeople, and supplied them with schools, a dispensary, and buildings for religious services, and thus made his works at Stoke Prior quite a model manufacturing establishment.

As regards the health of the operatives engaged in the salt manufacture, though many of them work in a very high degree of temperature during the greater part of the day, it is on the whole very good. An atmosphere impregnated with salt is, as a matter of fact, preservative against colds, rheumatism, neuralgia, and other ailments caused by exposure to cold and damp, which are so common among working men. Salt boilers, who are abstemious men generally, live to a good age, but unfortunately the very nature of their work is provocative of thirst, and leads to a great deal of intemperance among them. Salt boilers in Cheshire, as in Worcestershire, are paid at the rate of so much per ton; and when at full work a man can earn from 30*s*. to 35*s*. per week for making fine salt, i.e. after paying his "assistants," who help him in "drawing," drying, and warehousing it. For "firing" the pans, he receives something extra. A salt boiler, employing his family to assist him, can make about 35 tons of fine salt in a week, for which, at present rates, he would receive 3*l*. 10*s*. The employers deal

only with the salt boiler, or "salt maker," as he is called. Women are not generally employed in Cheshire; and at the Stoke Prior Works, in Worcestershire, Mr. Corbett some time ago succeeded, though after a great deal of trouble, in abolishing female labour altogether. Wages in Worcestershire, it is said, compare favourably with those in Cheshire, as in the former, employment is constant, while in the latter the workmen sometimes lose a good deal of time. It should be remembered, as bearing on the question of wages, that salt making, as it is called, is only drawing salt from the pans, and is therefore in reality only unskilled labour.

The manufacture of salt from *Sea Water* only requires a few passing remarks. In almost all hot countries during the summer months, immense quantities are made along the sea shore in earthen pans or shallow ponds by the mere process of solar evaporation, and in France at the present time this method is still in vogue. Sea gardens or salteries were at one time very common in the United Kingdom, particularly in Scotland, where also salt was manufactured by evaporating sea water by artificial heat; but since the total repeal of the salt duty, to be alluded to presently, this process has been entirely superseded by the brine-springs of Cheshire and Worcestershire. Nor can this be wondered at, when we remember that the amount of salt in sea water is very trifling compared with that in well-saturated brine. Though the southern oceans contain more salt than the northern, and some tracts of water more than

others, as, for instance, the Atlantic Ocean than the English Channel; speaking in round numbers, salt water contains only a little more than two per cent. of chloride of sodium, as compared with the 25 per cent. contained in good brine; or, to put it in another way, a gallon of salt water contains only ¼ lb. of salt, while brine contains from 2 lb. 4 oz. to 2 lb. 10 oz. In some countries sea water is only evaporated to a certain degree in the shallow pans or reservoirs, and the manufacture is afterwards completed by pouring the brine upon twigs, and sometimes upon burning wood, from which the deposited salt is afterwards collected.

It was long supposed that British salt was inferior to, or rather not so well adapted for the preservation of fish and other animal food as, the salt procured from France, Spain, Portugal, and other warm climates, where it was prepared by the spontaneous evaporation of sea water. Hence large sums of money used to be paid every year to foreign nations for the supply of an article which Great Britain possesses, beyond almost any other country in Europe, the means of drawing from her own internal resources. Some years ago Dr. Henry, the chemist, instituted a careful inquiry into the subject, feeling how important it was to ascertain whether this preference for foreign salt was founded on accurate experience, or was merely a matter of prejudice; and whether any chemical difference could be discovered to explain the superiority of the one to the other. The result was, that the slight difference in chemical composition discovered by him

was scarcely sufficient to account for those properties imputed to them. The stoved and fishery salt, for example, though differing in a very trivial degree as to the kind or proportions of their ingredients, are adapted to widely different uses. Thus the large-grained salt is peculiarly fitted for the packing of fish and other provisions. Its suitability for preserving food must therefore depend on some mechanical property; and the only obvious one is the size of the crystals and its degree of compactness and hardness. Quickness of solution, it is well known, is nearly proportional, all other circumstances being equal, to the quantity of surface exposed. And since the surfaces of cubes are as the squares of their sides, it should follow that a salt, whose crystals are of a given magnitude, will dissolve four times more slowly than one whose cubes are only half the size. That kind of salt, then, which possesses most eminently the combined properties of hardness, compactness, and perfection of crystals, will be best adapted to the purpose of packing provisions, because it will remain permanently between the different layers, or will be very gradually dissolved by the fluids that exude, thus furnishing a slow but constant supply of saturated brine. On the other hand, for preparing the pickle, or for striking the meat, which is done by immersion in a saturated solution of salt, the smaller-grained varieties answer equally well, or, on account of their greater solubility, even better.

Among the various uses of salt, other than as a condiment, is its application to the food of domestic

animals, being either added to their fodder or given them in the form of rock-salt to lick as they are disposed. It is also used as a manure for land, an ancient practice in vogue in Palestine and China more than 2000 years ago. At the present day there is still much questioning as to the use of salt as a manure, which has arisen partly from ignorance as to its chemical action, and from its injudicious application. The fact also, that it is speedily destructive of weeds when used in certain quantities, has helped to keep up a prejudice against it. However, by scientific farmers its use is well recognized, and each year it seems, that a larger quantity is being demanded for agricultural purposes. For such purposes it may be calculated, that about 200,000 tons are now annually used in the United Kingdom, chiefly in the form of finely-crushed rock-salt. Salt is also largely employed in the manufacture of the various salts of soda, especially the carbonate. The soda used in soap making and for other purposes was formerly obtained by burning marine plants, such as *Salsala Soda* and *Salicornia Herbacea*, on the coasts of the Mediterranean and other warm climates, the ash obtained being called *barilla;* while on some parts of the coasts of Ireland and Scotland an inferior article named "kelp" was produced by burning the *Fucus Vesiculosus* and other species of Fuci. The repeal of the duty on salt almost entirely superseded the manufacture of "kelp," the supply of soda being now furnished by the decomposition of common salt by a process invented by a French chemist, Leblanc, at the close of the last century. Salt is also

employed in the preparation of hydrochloric acid, in the glazing of stoneware, in the manufacture of soap, which it hardens, and in that of glass, to which it gives whiteness and clearness. It is largely used in metal-refining works, as it preserves the surfaces of melted metal from calcination by defending them from the air. It is employed with advantage in some assays, also as a mordant, and for improving certain colours, into which it enters more or less in many other processes of the arts.

It now remains to speak of the salt trade, its cost, price, and present position.

The interests of the trade are carefully watched over by the Salt Chamber of Commerce, which was formally installed at a numerous meeting of proprietors held at Northwich on the 30th of August, 1858, its fundamental principles being the formation of an efficient representative body for the extension, general advancement, and protection of the trade. The Chamber, of which all the chief salt proprietors in the kingdom are members, has energetically pursued the objects of its institution, and successfully extended the consumption of salt in markets already established, and brought about the opening of fresh ones. Its yearly reports are replete with useful and interesting information, in reference to the progress and requirements of the trade. I acknowledge my obligations to Mr. John Moore, the secretary to the Chamber, for much valuable information; as also to Mr. Hadfield, the London representative of the Chamber. It is hardly necessary to say that the salt trade in Great

Britain is now entirely unfettered and unrestricted, and has been so for the last fifty years. It seems that salt duties were first exacted in 1702, and renewed in 1732. In 1783 and 1785, Acts of Parliament were passed prohibiting the use of refuse salt by farmers, and from that time until 1819 the law compelled salt manufacturers to throw it into the river in the presence of examiners of the Customs, lest it should be used by farmers to defraud the revenue. In 1798 the duty was 5*s.* per bushel, which was subsequently raised to 15*s.*, thus making its cost thirty times greater than that of its manufacture. During the French war, the duty amounted to over 30*l.* per ton, and, when at its highest, produced a revenue of about 1,500,000*l.* a year; though it is not to be wondered at that such fiscal arrangements led to salt smuggling and a variety of devices for evading the duty. It was reduced in 1823, and finally ceased altogether in 1825. There are some who still think that an imposition of a duty of from half-a-crown to five shillings per ton, or even more, might be imposed without any adverse effect on the trade, and without its being felt by the consumer. But though a revenue of from a quarter to half a million might thus easily be obtained, such a proceeding would be so contrary to the spirit of modern commercial legislation that it is not likely to be seriously proposed, except under most extraordinary circumstances. The periods of great development in the salt trade appear to have been simultaneous with certain causes, such as the repeal of the duty, the increased use of salt in agriculture, smelting and manufacturing,

and especially when it became substituted for seaweed or kelp in the manufacture of soda, and led to the concurrent large increase in that trade. In 1671, when the Weaver was first made navigable to Winsford, only two salt-works were in operation at that place, and those on a very small scale. About the year 1825, probably just after the repeal of the duty, it appears that the whole manufacture of Northwich and Winsford did not exceed 250,000 tons annually, a quantity which, as will be seen from one of the subjoined tables, is now increased fivefold. In 1844 the export trade amounted to about 13,476,884 bushels of rock and white salt, of which quantity—

	Bushels.
Russia took	1,823,756
Denmark	462,576
Prussia	1,686,520
Holland	799,802
Belgium	1,041,028
Sweden and Norway	237,594
Germany	301,426
British North American Colonies ..	1,772,799
United States of America	4,664,430
Western Coast of Africa	374,452
New South Wales	125,801
Guernsey, Jersey, &c.	41,032

The remaining quantity was sent in small shipments to the West Indies, ports in the Mediterranean, River Plate, &c. The quantity retained for home consumption in the same year was estimated at 12,647,616 bushels, or 632,380 tons; thus making the whole salt production of the country equal to about 1,306,224 tons.

About two or three years ago the annual production of salt from brine alone was thus stated:

	Tons.
CHESHIRE:	
Northwich	450,000
Winsford	800,000
Middlewich	20,000
Wheelock and Lawton	100,000
STAFFORDSHIRE:	
Shirleywich and Weston-on-Trent ..	4,000
WORCESTERSHIRE:	
Droitwich	115,000
Stoke-Prior	105,000
Total	1,594,000

A return for the years 1875–76 gives the total quantity as 1,779,000 tons.

A small quantity is also manufactured in Ireland from the rock-salt worked at Duncrue, near Carrickfergus, which is dissolved into brine by water. The same is also done to a small amount at other places, and by the addition of rock-salt for strengthening weak brine, before it is evaporated.

The production of rock-salt for the years 1875–76 is given as follows:

	Tons.
Cheshire	158,044
Ireland	33,075
Total	191,119

This, with the production of white salt from brine, will give an annual aggregate of nearly *Two Million Tons.*

The following table, extracted from the Official Parliamentary Blue Book, will show the steady growth of the salt trade as instanced by the foreign exports.

Salt exported during five years:

	Tons.
1842 to 1846	1,608,308
1847 " 1851	2,195,605
1852 " 1856	2,876,906
1857 " 1861	3,201,409
1862 " 1866	3,075,840
1867 " 1871	4,011,659

whilst the home consumption is proportionately large; and it may be estimated that the total quantity of salt sent from the Cheshire district alone, is now about 1,500,000 tons annually. To take one instance of the rapid progress of the export trade, it may be mentioned that in 1864 the declared value of exported salt was 276,559*l.*, which in 1867 had risen to 445,941*l.* The increase in the salt trade may also be partly gathered from the progressive yearly increase in the number of salt-pans, which will be given in a subsequent table.

The ports from which Cheshire salt is shipped are: Liverpool, Runcorn, Weston Point, Hull, and Grimsby. To Hull and Grimsby the salt is sent by rail; to Liverpool, Runcorn, and Weston Point, by water, either down the river Weaver, which by an Act of Parliament passed in 1721 was made navigable, and is continued navigable from Winsford Bridge to the Mersey; or else down the Trent and Mersey, and Bridgewater Canals. The shipping ports for Worcestershire salt are Gloucester and Bristol, but, as

before stated, the chief manufacture at Droitwich and Stoke is for the inland trade. The following table of the returns from the three chief shipping ports for a year and a half, ending June 30th, 1876, will give the several destinations of our exported salt, which stands *third* on the General Export Returns, coal and iron only ranking before it:

	One year to 31st Dec. 1875.	Half year ending 30th June, 1876.
From LIVERPOOL:	tons.	tons.
To United States	212,532	86,982
„ British North America	54,807	31,661
„ West Indies and South America	4,442	3,822
„ Africa	25,507	12,605
„ East Indies	311,107	97,836
„ Australia	24,918	7,778
„ Baltic and North Europe ..	101,989	87,904
„ France and Mediterranean ..	889	674
„ Coastways	72,268	39,429
„ Holland and Belgium	62,917	25,809
Total from Liverpool ..	871,376	394,500
From RUNCORN:	71,018	39,628
„ Weston Dock	90,093	53,480
Grand Total	1,032,487	487,608

From this table, in which both white and rock salt are included, it will be seen that North America is the best customer of the salt proprietors. After a long contention between the advocates of free trade and the upholders of the salt monopoly in the States, the former succeeded, in 1872, in getting the import duties on salt reduced to 8 cents for "bulk,"

and 12 cents per 100 lb. for "sack" salt, and the effect of this reduction was soon seen. American shipments are almost entirely made at Liverpool, as American vessels which bring over cotton thus get freights back. The reduction of the duties therefore by the States has not only been to the advantage of the Cheshire manufacturers, but it has materially benefited both English and American shipping.

Our next best customer is India. Till within the last thirteen years, salt making and selling was entirely a Government monopoly over the whole dependency, but the salt produced, whether from washing salt soil, from the mines in the salt range in the Punjaub, or from evaporation of sea water on the coast, was, and is still, of a very inferior character, more or less dirty in colour, and containing from 10 to 12 per cent. of impurities. Various changes in the fiscal regulations have been made from time to time, but the monopoly has always been productive of great jobbery and a variety of abuses, in consequence of the salt passing through so many hands. Six million pounds annually was a large revenue for the Government to secure, but this was obtained at the expense of the natives, who in some districts spend as much as one-sixth of their annual earnings upon what is absolutely a necessary of life to a people whose food is peculiarly insipid, and who use little fish or animal diet. As long ago as 1831–32, a Parliamentary committee stated that the price of salt in some districts of India was about 288 per cent. above the original cost and charges. It also expressed an opinion that the Bengal Presidency might obtain a cheaper supply by importation

from the coast of Coromandel, Ceylon, and elsewhere, and even from Great Britain, than by the existing system of home manufacture, and recommended that the Government should contract for the delivery of salt, by advertisement, into the public warehouses of the port of Calcutta, at a certain price per ton, and that in the interest of the natives the home manufacture should be gradually diminished. It was not, however, till 1863, through the instrumentality of Sir Charles Wood, that the Government monopoly was abolished in the Bengal Presidency, and salt admitted *into bond* at Calcutta, with a Customs duty of about 6*l.* per ton, payable on its being taken out. This arrangement has continued ever since, and while it has conferred a great boon by opening a fresh market to English manufacturers, the revenue of the Indian Government has not suffered, for it still derives upwards of six million sterling per annum from salt.

The Salt Chamber of Commerce has for many years been in communication with the Home Government, pressing upon it the desirability on several grounds for relinquishing salt manufacture in India, and equalizing the duties in all the Presidencies. That this would lead to an increased consumption of salt, and by affording, as it would, an opportunity for reducing the large army of excisemen and other *employés*, in reality augment the Indian revenue, has been most ably set forth in a pamphlet recently published by Mr. H. E. Falk, Chairman of the Salt Chamber of Commerce, who thoroughly mastered the subject during a visit to India made by him in 1874–75.

The following table will show the number of Salt

Pans in existence on the 1st of July for the last ten years:

District.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.
Winsford	459	489	503	517	523	541	554	567	595	616
Northwich	293	316	343	351	355	388	392	400	434	462
Middlewich	..	..	..	13	13	13	13	11	11	12
Sandbach	..	..	..	60	60	61	62	67	67	67
Droitwich District ..	..	..	..	137	141	145	148	153	154	154
Total	752	805	846	1078	1092	1148	1169	1198	1261	1311

The number of Firms now engaged in salt manufacture is over fifty. The subjoined table will show those which have the largest number of pans at work:

Firm.	No. of Pans.
WINSFORD:	
Executrix of late G. Deakin	92
Joseph Verdin and Sons	86
Richard Evans	60
Cheshire Amalgamated Salt Co.	57
H. E. Falk (President of Salt Chamber of Commerce)	43
National Patent Salt Co.	28
NORTHWICH:	
W. Worthington	50
Joseph Verdin and Sons	55
British Salt Co.	34
Victoria Salt-works Co.	30
SANDBACH:	
Cheshire Amalgamated Salt Co.	35
Wheelock Iron and Salt Co.	32
DROITWICH DISTRICT:	
John Corbett	154
Droitwich Salt Co.	

As on an average a salt-pan will make about 1000 tons per annum, the business of a firm can be judged by the number of pans which they have at work.

The *Price* of salt depends mainly on the cost of fuel, and partly on that of iron, which is used for the pans and for other parts of the plant, and soon perishes from the action of the salt, while at the same time, like as in other articles, the price fluctuates according to supply and demand. Common salt, which is the cheapest made, forms the standard of price, all the other qualities being regulated by it. For many years, as coal remained pretty steady, salt fluctuated but little. From 1845 to 1850, the average price of common salt was 7*s.* 6*d.* per ton at the works. It fell as low as 5*s.* 3*d.*, and then advanced to 12*s.*, but for short periods. From 1850 to 1860, the price was much the same as in the previous five years. When the American war commenced, prices fell, and during the war averaged about 4*s.* 3*d.* at the works. Some lots were sold as low as 3*s.* 9*d.*, the lowest price ever known. In 1865 the price advanced, and since that period it has been from 6*s.* upwards. In 1872 it reached 20*s.* In 1873 it commenced at 12*s.*, but soon rose to 15*s.* The usual rate of prices was—butter and fishery salt, 1*s.* 6*d.* more per ton than common; "shutes stoved," 3*s.*, and "handed squares," 5*s.* more than common. This was in the days of low prices; but now the difference is generally greater, the previous figures being represented by 2*s.* 4*d.* and as much as 7*s.* respectively.

From the above remarks, it may be gathered that

the salt trade, important though it be, is one which does not hold out any very strong inducements for capitalists to enter. It is somewhat precarious in its nature, and easily affected by external circumstances. It is mostly in private hands, by which it seems better managed than by companies, few of which have paid dividends of an attractive character. Here and there, fortunes have been made; but fortunes have also been lost, in experiments and failures in "pricking," i.e. finding brine. It must be remembered, too, that in several localities of the salt districts, symptoms have long been shown of a failure in the brine supply. Many shrewd capitalists, however, outside the trade, evidently think that more might be made of it. In 1872, for instance, several leading capitalists of Manchester invited the salt trade to a conference, having for its object the absorption of the whole salt trade into a Limited Company, which should buy up all existing salt-works, and secure, as far as possible, all salt lands in the neighbourhood of the river Weaver and the railways. The whole question was discussed between the parties interested at Northwich, but no tangible result was arrived at, and the matter seems to have dropped. The movement, however, did some good, by showing salt proprietors the real value of their investments; and also, that if they continue united for their common good, and refuse to be the sport of jobbers and shippers, who have so long exercised an undue influence over the trade, they can secure for themselves that legitimate return for their capital to which they are fairly entitled.

PRESERVATION OF FOOD.

By J. J. Manley, M.A.

The preservation of food substances, animal and vegetable, can hardly be said to hold a very important place among British Manufacturing Industries, strictly so called; but it is more than probable that before many years have passed, this industry will be very largely extended. The high price of meat has of late directed much attention to the subject, and vigorous attempts have been made to supply this country with animal food in a preserved form from our Australian colonies and elsewhere, while the increase of our royal and mercantile navy has also directed increased attention to meat preservation at home, i. e. of meat preserved in a fresh, though cooked, state. As long ago as 1689, John White and William Porter obtained a grant from the Crown "to hold and enjoy for fourteen years" the sole right of preserving animal food, which they warranted would keep sweet for any number of years in any climate. But the process does not seem to have produced any great result. Only three patents for food preservation were described in the eighteenth century, while as many as 117 were specified in the first fifty-five years of the present. The number now amounts to many hundreds, though in numerous instances only varying in detail, and not in principle.

The several methods of preserving meat may be classified roughly under four heads:

1. The simple process of *Drying.*
2. The use of *Cold.*
3. The use of *Chemical Antiseptics.*
4. The *Exclusion of Atmospheric Air;*

to which perhaps might be added the process of Pressure. The *Drying* process is a very old one, and probably almost contemporaneous with man, either as an herbivorous or carnivorous animal, but it can hardly be looked upon as a scientific process in connection with food preservation, though a large number of patents have been taken out for it. The expression of water from animal and vegetable substances by artificial means, and their desiccation by exposure to the sun or hot air, leaves their fibre and a great part of their dried juices in such a state, that they are incapable of destruction by the natural process of decomposition, being only affected by time, like other inorganic matter. Thus we can see at the present moment dried poultry at the British Museum, which has been taken from Egyptian tombs, where it was placed some thousands of years ago. *Charqui,* or South American dried beef, is perhaps the best form of dried meat known in this country. Dried vegetables are put up in considerable quantities by Messrs. Gillon and Co., of Leith, and by other preserving firms in Scotland, as also by Messrs. Whitehead, of Lime-street Square, London. In several soup "tablets" we have dried meat and vegetables together, the

"Ebswurst," or portable soup, supplied to the Prussian troops in the late war, being well known. Meat biscuits are also another form in which dried meat is presented to us, while dried ox-tongues from all parts of the world are a considerable article of commerce.

Preservation of meat by *Cold* can hardly be called a scientific process, being no more than a temporary expedient for transporting meat from one country to another by placing it in immediate contact with ice, or by reducing the temperature round it by ice or some other artificial means. That flesh can be preserved for an almost indefinite period is well known, for animals themselves have been found in a perfect state of preservation in the Arctic regions, where they must have been buried for centuries. In Russia, Canada, and other Northern countries, it is a common practice to slaughter fat animals and preserve their carcases, by burying them in the ice or frozen earth from the middle of November to the early part of May. Our markets are supplied with fish and poultry, especially in the winter months, packed in ice, from many different countries, and it is only the cost of natural and even of artificially made ice, which prevents our regularly obtaining fresh uncooked meat from Australia, South America, and elsewhere. Mr. J. Harrison, of Melbourne, was very successful at one of the recent Exhibitions in that city in preserving whole carcases and large joints for a considerable period by means of ice; and so satisfied was he of the perfection of his system, that in 1873 he undertook to bring to England a large quantity of meat packed in what may

be called an ice-house, on board the ship 'Norfolk'; but the arrangements were imperfectly carried out, and the ice supply failed before the voyage was completed. During the winter of 1875–76, some hundreds of tons of beef, mutton, and pork were brought from America by means of refrigeration, and sold in the Metropolitan Meat Market at prices very little below those of first-class meat; and I see it noted in the 'Society of Arts Journal,' August 25th, 1876, that the importation has been going on during the preceding months. It may, however, reasonably be expected that, before long, uncooked meat will be regularly brought from various parts of the world by means of refrigeration without any risk, and at a price which will not only remunerate the importers, but greatly benefit meat consumers in this country. To effect this, most persons rightly look to the application of the "downward draught" system of refrigeration as perfected and patented by Mr. G. Kent, of High Holborn, who has demonstrated, by the construction of large ice chambers in ocean-going steamers, hotels, butchers' shops, and establishments like the Alexandra Palace, that his method is the most effective, and at the same time the cheapest yet discovered.

The use of *Chemical* agents, called *Antiseptics*, in food preservation, has been carried out in various ways, but with only partial success, the agents employed giving more or less an unpleasant flavour to the substance to which they are applied. Foremost among these agents is common salt, which has been used from the earliest times; but it tends to a great

extent to extract the soluble constituents of meat, depriving it of its stimulating and nutritious elements, and rendering it hard and indigestible. The curing of pork, in the form of hams and bacon, with or without the additional process of smoking, is of course carried on to a large extent in several parts of the United Kingdom, but any detailed account of this industry hardly seems to come within the scope of the present chapter. It may be mentioned also that other saline substances, as saltpetre, acetate of ammonia, sulphate of potash, muriate of ammonia, &c., have also been employed as preservative agents, but by no means successfully, though several patents have been taken out for their use. Moreover, bisulphite of lime, sulphurous acid gas, and dilute sulphuric acid have been employed in various ways towards the desired end; but notwithstanding our advanced state of chemical knowledge, it can scarcely be said that the use of chemicals has as yet given us a fresh preserved meat, which, when cooked, is acceptable to the taste. Professor Gamgee some time ago made experiments in subjecting animals to a chemical process, even before death, with a view to the after-preservation of their flesh. They were caused to inhale carbonic oxide gas, which rendered them insensible in about two minutes, when they were killed and their carcases hung up in a chamber, full of carbonic oxide and boxes containing charcoal charged with sulphurous acid. After remaining for twenty-four to forty-eight hours in this air-tight chamber, the carcases were hung up in dry air and kept for many months. Injections of various chemicals in

animals' veins before or immediately after death have also been tried, but no satisfactory result has followed. Taking all things into consideration, it is hardly likely that the use of chemicals will solve the question of meat preservation.

I now come to the processes of preservation by means of the *Exclusion of Atmospheric Air.* This has been attempted, but with only partial success, by means of an air-pump applied to the receptacles containing the meat. Another plan has been, to coat the substance to be preserved with some material impervious to the air, such as gelatine, common glue, gutta-percha, &c., or by dipping it in melted fat several times, thus to obtain an air-tight outer covering. But this device cannot be said to have accomplished the object in view, it being found in most instances impossible to arrest putrefaction without the additional use of spices or chemicals, the atmospheric air in the interstices of the meat itself gradually tending to bring about decomposition. The only method, after all the experiments made, whereby a perfect preservation can be effected, is the application of heat to the vessels, so that the atmospheric air is entirely expelled and an absolute vacuum produced: and to M. Appert, of Paris, must be attributed the credit of having established this process in 1810.

Without entering into a scientific discussion, as to whether the true theory of this process of preservation by applied heat is the destruction of the "microscopic germs," which are alleged to be the cause of putrefaction, it may be taken for granted that the oxygen gas

is entirely expelled, not only from the receptacle in which the food substance is preserved, but from the substance itself. That a perfect vacuum is obtained, is shown by the fact, that the tins become concave both at the top and bottom, and in many instances the sides "collapse"; and the audible in-rush of air, when the opening knife is first inserted, points to the same conclusion. The process may be thus briefly described. The meat, fish, poultry, or vegetables are put into tins of various sizes, which are then placed in "baths" raised to a temperature of between 260° and 270° by the addition of chloride of calcium to the water. The tins are immersed to about two-thirds of their depth, a small orifice called a "pin hole" being left open on their tops for the escape of the steam. The cooking takes from one to three hours, according to circumstances, at the end of which time the "pin hole" is soldered up and the tins taken out to cool. This is called the "chloride of calcium" process. The "Aberdeen process" differs from this, in the tins being placed in the bath, hermetically closed and entirely immersed, and from time to time being raised out of the bath on iron frames, or "gridirons," in order that the small apertures in the lids previously soldered over may be momentarily opened for the escape of steam, and closed again. The "brogging" of the tins, as it is called in Scotland, is performed once, twice, or even three times, according to the size of the tins and the nature of the substance to be preserved, during the cooking process. In some cases, only salt is added to the water, in others steam retorts are used. This hot-bath process in

some form or other is that which is used in Australia, New Zealand, and other countries, from which preserved meat in tins has been sent in such large quantities of late years to England. In 1872 no less than 17,518 tons, valued at 890,700*l.*, were imported, chiefly from English colonies; but the supply has since then somewhat fallen off, partly because the price of meat has gone up in the colonies, and partly because, in its preserved form, it does not commend itself greatly to the public taste in this country. In 1874 the declared value of the importations was 751,709*l.*, but in 1875 it fell to 593,054*l.* The truth is that, though the hot-bath process ensures perfect preservation, as shown by the fact that meat preserved in this way forty or fifty years ago, and subjected to all vicissitudes of climate, is still perfectly good, the taste of the meat as well as its appearance is considerably impaired by the over-cooking which it receives. Whether it chemically loses any of its nutritive properties, as many aver, need not here be discussed. At present the application of the hot bath in the above-described processes, which are all substantially the same in principle, seems to necessitate this over-cooking, and renders the meat, from its softness and vapidity, generally unacceptable. An improvement however was effected in these respects by the "vacuum" process, patented by Mr. Richard Jones, who thus described it:

"We put the meat into tins, either with or without bone, in joints or otherwise. The tins are filled quite full, and are soldered up entirely, with the exception

of a small tube, about the size of a quill, which is soldered into the top of the tin. The tins are then put into a bath capable of holding ninety-six 6 lb. tins. Along the centre of the bath runs a tube carrying twelve taps, into each of which may be inserted a tube from eight tins, there being eight stuffing boxes to each tap, four on each side. The tube communicates with a vacuum chamber. The bath contains a solution of chloride of calcium, which boils at a temperature of from 270° to 280°. In commencing operations, the bath is gradually heated until it gets to about 212°. Communication is then opened with the vacuum chamber, and the result is, that as water boils at about 100° *in vacuo*, the water is carried off, in the shape of steam, into the vacuum chamber, where it is condensed. The tap is then turned, so as to shut off communication with the vacuum chamber, and the meat is cooked at a high temperature, until complete preservation is effected. We then go on cooking the meat, occasionally turning the taps, just to do what engineers call priming, in order to draw off any fluid that may be in the tins. After it has been thus cooking for about two hours at 250°, it is in a preserved state." The extra trouble and expense of Mr. Jones's process seems to be the main cause, why it is not generally adopted.

Scotland takes the lead in this industry of the manufacture of preserved food, and Aberdeen has for many years been its head quarters. In that country there are nine or more food-preserving establishments, of which five are at Aberdeen. It may seem strange

that the famous "Granite City," situated so far north, should have been made the centre of this trade, the products of which are sent to the most distant parts of the world. The reason, however, is that there the best Aberdeenshire and Highland beef, known in the London markets as "Prime Scot," and the best black-faced Highland mutton, can be bought at the cheapest rate, and that, with the exception of salmon (though this can be got cheaper there, generally speaking, than elsewhere), a variety of fish can be obtained at an almost nominal price, herrings (four to the pound) costing about one farthing each, and cod from a penny to a penny farthing per pound, according to the season. A few years ago I visited Aberdeen for the express purpose of witnessing the preservation of food, as carried on at the manufactories in that city; and from what I saw, I can bear witness that this industry is conducted in a fair and business-like manner, the different establishments being models of order and cleanliness, whilst the materials used and the care employed in preserving them offered no opportunity for hostile criticism. The leading firm in Aberdeen is that of Messrs. Moir and Son, which opened business in that city as far back as 1822, though for some years previously it had been engaged in the preserving trade in another locality. It at first chiefly directed attention to the preservation of salmon, mainly for exportation, but subsequently added to its business other kinds of fish, meat, poultry, and vegetables, as well as of soup, and a variety of what may be called compounded dishes. The establishment covers a large area of

ground, having been considerably added to of late years; and the hands employed, chiefly young women, number about 250. The quantity of meat preserved annually was till recently about two million and a half pounds, but this part of the business has not been so much pushed of late, in consequence of the greatly increased price of meat, and partly because more attention is paid than formerly to the preservation of fish, game, and poultry. Generally speaking, it is the fore-quarters which are preserved in the form of roasted, boiled, corned, stewed, or minced beef, the hind quarters being sent in large quantities to the London markets, and finding their way into the shops of only the first-class West-end and other butchers at the top price. Some years ago these fore-quarters could be bought wholesale by the Aberdeen preservers at 3*d.* per pound; of late the price has more than doubled. The first-rate quality of all the articles used in Messrs. Moir's establishment, and the extreme cleanliness with which the operations are conducted, are the chief and most satisfactory features which strike a visitor, the young women being scrupulously neat, with their white aprons almost up to their necks, and their arms bared as if for a ball room, plainly showing that the greatest care is taken in the manipulation of the provisions during the process of preparation. The beef was evidently the best which the market could produce, and the carcases of some score of sheep or more hanging in one of the rooms bore witness to the excellence of Highland mutton. During the Crimean war, the resources of Messrs. Moir's manufactory were

severely tested, but did not fail to do what was demanded of them, no less than 5000 tins, containing 6 lb. of meat each, being turned out daily for six weeks consecutively. Some remaining samples of this meat, as also a tin which had been "put up" more than twenty-five years ago, when opened, were as fresh and sweet as on the day when they received their hot baths. In addition to the almost fabulous quantity of articles bought by Messrs. Moir for preservation, their farm, hard by Aberdeen, furnishes no mean supply. Strawberries and other fruits are here grown by acres, and, preserved chiefly in large tins, find their way with other tinned goods to India, China, and Australia, which latter country, though it is now exporting for our use peach and apricot preserves, values Moir's strawberry jam before all other preserves. The art of compounding rotten figs and other vile odds and ends into "family" jam does not seem as yet to have become known, or at least practised, so far north as Aberdeen. On the farm also are produced tons of all kinds of vegetables, and an average of 1300 pigs here enjoy a fattening existence, happily unconscious of the various, though not "base, uses," to which they will be put by Messrs. Moir. To enumerate and make but a brief remark on each article and form of article which this firm "puts up," would fill a volume, its trade list containing some hundreds of different food preservations and provisions in endless variety. The manufactory of Mr. J. Morton, built not many years ago for the express purpose of food preserving, covers nearly half an acre of ground, and is a

continuous granite building two storeys high, built on the four sides of an open quadrangle which forms the centre. It is admirably arranged throughout all its departments, from the tinsmith's shop to the end of the store rooms, where the tins painted and labelled are packed in solid blocks, ready to be despatched to their several destinations. Order and cleanliness reign supreme throughout the whole establishment. Mr. Morton during the fishery season makes the preserving of herrings a special feature in his business, and the arrangements for thoroughly cleansing them before they are put in the tins are very complete. I also visited the establishment of the Food Preserving Company, which employed Mr. Richard Jones's patent preserving method, already noticed, and a close inspection of the process from beginning to end plainly proved that it was not fairly open to the allegation, that the action of the vacuum extracts from the articles preserved a large proportion of the natural juices. For instance, after fowls or mutton have been preserved, the condensed liquid is perfectly colourless and tasteless, requiring a considerable imagination to detect in it the flavour of mutton or chicken broth. The same remark applies to the beef, of which Mr. Anthony Trollope had a sample set before him in Australia, and of which he says in his recent work, recounting his experiences in that country, "What may be the speciality of Jones's patent I did not learn, but as to that special joint, I protest that I never ate better cold roast beef in my life. It was not overcooked, and judging from its colour, appearance, and flavour,

it might have been cooked and put into the larder on the previous evening." The Food Preserving Company has, however, lately ceased business. The other firms of meat preservers in Aberdeen are those of Messrs. Hogarth, who have been in the habit of preserving large quantities for the Royal Navy, and of Messrs. Marshall, at both of which the ordinary methods of preservation are pursued, unless the use of steam retorts by Messrs. Hogarth can be considered as a distinctive feature. The firm of Messrs. John Gillon and Co., of Leith, is also deserving of notice. It has been in existence since 1817, when it was chiefly employed in the manufacture of British wine, for which it is still celebrated; but in 1829 it turned its attention to food preserving on a large scale, and it now employs about 150 hands, and a still larger number in the fruit season. Messrs. Gillon and Co.'s preserved meats will bear comparison with the very best; and for their essence of beef, they may justly challenge all other producers of a similar article. According to Professor Christison, an eminent authority on such a matter, this meat juice is not only a stimulant, which is the main feature of Baron Liebig's production, as acknowledged by himself, but "a nutriment much in the same category as beef-tea;" and he adds that "no good beef-tea can be made so cheaply as with this preserved meat-juice, a tin of 4 ounces making 16 of strong beef-tea." Mutton and chicken juices are prepared by Messrs. Gillon by the same method as that of beef; and medical men are agreed, that in cases of dangerous illness, and during the process of convalescence, these preparations are

invaluable. These juices are specialities of the firm, which has also gained a great reputation for its preserved Scotch salmon, hardly distinguishable from salmon cooked in the usual manner.

Messrs. Gillon also preserve a variety of national dishes, such as Scotch broth, cocky-leekie, hotch potch, sheep's head and trotters, and haggis, which are exported to the farthest ends of the earth, so that Scotchmen in every clime can be gastronomically reminded of the culinary delicacies of their native land. All kinds of vegetables accompany the preserved meats, sometimes in the same tins, though in this branch of preserving, palm must be given to the French houses, which, among other things, produce *petits pois* far superior to any of English or Scotch "putting up." But to Messrs. Gillon must be given the credit of having first preserved plum puddings, which perhaps, more than any other article of food, would suggest to Englishmen abroad pleasant reminiscences of home. An interesting part of the work at the Leith manufactory is the making and soldering of the tins by machinery, part of which is patented, whereby a few men and boys can turn out daily an amount of work which by the usual method would employ three or four times the number.

In England there is not much done in the way of meat, fish, or vegetable preserving. The largest firm is that of John M'Call and Co., of Houndsditch, who, in addition to being the agents for the Melbourne Meat Preserving and Western (Colac) Companies, the latter famous for its tinned rabbits in various forms, have

acquired a high reputation for tinned soups, vegetables, and a variety of other preserved articles. The Paysandu ox tongues, put up by this firm in tens of thousands in Uruguay, have during the last year or two obtained a world-wide name as one of the most successful of meat preservations, while the pressed and corned beef from Chicago, introduced by the same firm into the English market in the summer of 1876, is very far superior to any similar article yet offered to the public, and leaves little to be desired in the way of perfect preservation, its remarkable firmness being produced by hydraulic pressure before cooking in the tins. Messrs. Crosse and Blackwell are also famous for their tinned soups, which are popular both for home consumption and in the foreign market. Among other specialities may be mentioned the curried fowl and rabbit preserved in tins by Mr. Halford, of Upper St. Martin's Lane. He was once *chef* to a Governor-General of India, and in that country learnt the real art of curry making. His curries, being prepared with fresh herbs sent in hermetically-sealed tins from India, may be considered among the very best preserved food preparations. They were supplied in large quantities to the 'Alert' and 'Discovery' for their Arctic voyage.

The above necessarily brief details of the food preserving in this country may help to direct more attention than hitherto has been given to a subject, not only of interest in itself, but of considerable importance in connection with the question of our food supply. If the Scotch and other firms, instead of confining their attention mainly to the shipping and

export trade, would lay themselves out more than they have done for supplying the home public also, they would probably find it answer their purpose. But they seem somewhat averse to this, probably from the fear that the prejudice existing against "tinned" provisions would militate for too long a period against their effort, for it to become a trade success. At the present moment Scotch and English preserved provisions are highly appreciated in every part of the world, except in England. The tins may be said to strew all our colonial possessions and foreign settlements, as they did the tracks of armies and camping-grounds in the late Franco-Prussian war, and, still more recently, in the Ashantee campaign. They are to be found in China, India, the Australian Bush, Central Africa, and at the North Pole. It is at home in our daily domestic life that this kind of food is little known, and less used. And yet if its excellence and cheapness were once ascertained, it is probable that few households would be without it in some form or other.

No notice of food preservatives would be in any sense complete without allusion to the preservation of milk. The credit of first condensing, or rather concentrating milk, is due to a Frenchman named De Leinac, about twenty-six years ago, from whom the process was obtained soon afterwards by Mr. E. D. Moore, a medical man attached to the Court, who at manufactories in Staffordshire and Middlesex, manufactured concentrated milk, and also made a combination of it with cocoa. In 1857, Mr. House, now of

76, Minories, on the retirement of Mr. Moore, whose manager he had been, took up the business, and, on an "improved patent," has continued it ever since. It was from Mr. House, through a Captain Fletcher, that Mr. Gail Borden, of New York, got his idea of preserved or condensed milk; for though Mr. House calls his "concentrated" milk, the process differs little from that of producing "condensed" milk, the former being obtained by evaporation of the water from the milk in open pans, the latter by evaporation in closed vacuum-pans. These facts show that primarily to a Frenchman, though mainly to an Englishman, the credit of first producing concentrated or condensed milk is due, and not to Mr. Borden, who, from having perhaps made some improvements in the process used, and developed the trade, is sometimes credited with originating the whole matter. I have recently tasted a sample which was put up in the year 1858, and since then has made a voyage to Calcutta and back. It was perfectly sweet and good, though it had become more solid than when first put in the tin. It cut and tasted very much like an extra rich blancmange, but was capable of being reduced, or rather expanded, into simple sweetened milk by the addition of water. It was with Mr. Borden's process, and perhaps some improvement in the working of it, that the Anglo-Swiss Company established itself in Switzerland, at Cham, in the canton of Zug, in 1866, and soon began to send condensed milk to this country. In consequence of the increasing demand for this article, the company during the year 1874 opened a manufactory

at Chippenham, where substantially the same kind of condensed milk is produced. The company, which has recently incorporated with itself the Aylesbury Company, established in 1871, has also works at Aylesbury. The supply of excellent milk from some of the best pastures in England will doubtless commend the choice of the situation. I visited the works, and watched the whole process of condensing milk not very long ago. Steam is got up at six in the morning, and the farmers, who live within from one to ten miles of the factory, begin to deliver their milk about seven. It is at once emptied from the tin cans generally used in the trade into a trough, which conducts it through sieves into a large tank holding about 800 gallons. Hence it is drawn into open metal cylinders, which are slung up by a crane, and placed in a hot bath in tanks, somewhat like the tins of meat in the preserving process. These are then emptied into funnel-shaped vats, when the hot milk is drawn up through a pipe in the centre into the condensing pans on the upper floor. The sugar used for its preservation having been mixed with it, it is subjected to somewhat low heat for two or three hours, while the evaporation of the water is taking place and the milk gradually condensing. When this is completed, the milk, then about the consistency of liquid honey, returns by a pipe into a lower room, and is received again into the open cylinders, which are swung into the central tanks—this time being filled with cold water—for the purpose of cooling; the regulation of the temperature during the whole process being a

matter of the greatest nicety. Thence it is taken to the filling room and run into 1 lb. air-tight tins, which are soldered up and packed in cases of four dozen each. The milk gradually thickens up to five or six months, after which it remains of the same consistency, and will continue good for years, and in all climates, indeed as long as the tins themselves continue sound; and even when opened, remains sweet for weeks. Great cleanliness is observed throughout the whole process. Even the empty milk cans from the farmers are scrubbed in hot water, and a strong jet of steam, followed by one of cold water, is violently impelled into them. In addition to this, the floor of the lower room is constantly deluged with streams of water supplied from the Chiltern hills. The milk received from the farmers, at about 2*d.* per quart, is tested in a variety of ways several times in the week, and some is stood in pans to test the rise of cream, a record of which is carefully kept. The contracts with the farmers are very stringent, and if anything is found wrong with the milk, the Company reserve to themselves the right of returning it, and at once throwing up the contract. They are careful also to examine the police records of the district, to see if any of the farmers whose milk they take have any cases of diseased cattle on their farms, which they are bound by Act of Parliament, under heavy penalties, to report to the police. The sugar used is of the best refined kind, some of it being beetroot. Adulteration would be impossible, and if attempted, would at once defeat the great object; and as the milk is sold only in the

Company's tins, hermetically closed and labelled, it is impossible for retailers to tamper with it. All that is taken from the milk is the water, which, in milk direct from the cow, constitutes as much as 80 parts out of 100. Improbable as this statement may seem, there is no doubt about it; and the proof is in the stream of colourless water which runs continuously from the condensers. This it does to the extent of about 85 parts out of 100; consequently, only about 10 or 12 parts of water remain in the bulk of the milk when condensed; the caseine, butyrine, and other solid and nutritive substances, remaining intact in their original form. This may easily be proved by adding to the condensed milk the equivalent of its original water, say three parts to one, and leaving it to stand in an ordinary dish, when it will raise cream in very nearly the usual proportion, though this action is somewhat impeded by the presence of the sugar. A further demonstration is afforded by the fact, that the condensed milk and added water will churn into butter, when raised to a temperature of about 40°. Early in the year 1876, another company was formed under the title of "Hooker's Cream-Milk Company," 104, Queen Victoria Street, E.C., to condense milk according to the method of Mr. John Hooker, F.C.S. A sample of his condensed milk was shown in an *open* vessel in the Food section of the International Exhibition, at South Kensington, in 1873, the sample having been manufactured two years before. In the month of June, 1873, a portion of it after dilution with water was churned into butter. At the close of

the Exhibition, the sample passed into the hands of the Society of Arts. It was found perfectly sweet in June, 1874, and in September, 1875, and on both occasions produced excellent butter. The remainder of the sample was in 1876 despatched to the Centennial Exhibition at Philadelphia, where it arrived in a perfectly sound condition, though it had been exposed to the air in an open vessel since 1871. Mr. Hooker's process has thus a great advantage over that of the Anglo-Swiss and other companies. The same process is also admirably adapted for producing *unsweetened* condensed milk, and probably before this article is published, the London public will be offered the unsweetened article, which for many years past has been largely consumed in New York. So popular has condensed milk become, that within a few years its production is likely to become a very important industry.

A few words in conclusion in reference to the "condensing" process as applied to beer. Mr. P. E. Lockwood, of the Anglo-Swiss Milk Company, must have the credit for this "happy thought." He found that beer of all kinds could be treated like milk, and its bulk similarly reduced by condensation. The value of the discovery consists mainly in the fact that the enormous expense of shipping English beers to all parts of the world can be reduced to a mere trifle, while the "condensed" beer can be brought back to the original state by the addition of water, and that without any perceptible deterioration of quality. This is decidedly one of the most interesting experiments in

modern food preservation; and it is being practically carried out by the London and Burton Condensed Beer Company, of Gresham House, Holborn Viaduct. The field for this new industry seems almost unlimited. The manufacture of "solid wort" has also been in existence for some years at Margate, by Messrs. Mertens, who have succeeded in opening up a market in India and the colonies; but this is a very different thing from the condensed beer, the latter containing *all* the ingredients of beer, which the solid wort does not.

The above is a necessary brief review of food preservation. The subject in its various branches is still attracting considerable attention, and there is every reason to believe that many successes are in store for those who persevere in a cause in which the general public is deeply interested.

BREAD AND BISCUITS.

By J. J. Manley, M.A.

It may be taken for granted that bread, using the word as simply meaning a mixture of bruised or unbruised cereals and water exposed to the action of heat, was known in the earliest times of man's history, and probably soon became, as it has since continued, the "Staff of Life."

The most primitive way of making bread was to soak the grain in water, subject it to pressure, and then dry it by natural or artificial heat. An improvement upon this, was to pound or "bray" the grain in a mortar or between two flat stones, before moistening and heating, and from this "braying" some etymologists consider the word "bread" (brayed) derived. A rather more elaborate bruising or grinding of the grain leads to such simple forms of bread as the oat cakes of Scotland, which are prepared by moistening oatmeal with water containing some common salt, kneading with the hands upon a "baking board," rolling the mass into a thin sheet, and ultimately heating it before a good fire, or on an iron plate, called a "girdle," suspended above it. In a similar manner are prepared the barley-meal and pease-meal "bannocks" of Scotland, as also some of the "scones" of

the same country and parts of India, the "passover cakes" of the Jews, and the Australian "damper," made of wheat-flour, though the sheet of dough in the latter case is made much thicker. The Indian corn-meal, kneaded with water and fined, affords the "corn-bread" of America. All these kinds of bread are *unleavened*, i. e. no leaven is added to the dough to excite fermentation. The operation of making and baking is therefore merely a mechanical one, no strictly chemical changes being brought about.

On the other hand, in the process of making *leavened*, or fermented, bread, a chemical action is induced by the use of leaven or some substitute for it: and this action is called *Fermentation*, and takes a considerable time in its operation. The materials employed in the manufacture of ordinary wheaten bread are flour, yeast, potatoes, salt, and water; and in mixing these in due proportions and at the proper times, in watching and regulating the chemical changes which take place during their combination, and in properly baking the mixture, consist the science and skill of the baker.

But in order to understand the chemical action of fermentation, it is requisite to know the nature of the different substances which constitute ordinary *wheaten flour*. It is composed, according to Vogel, chiefly of starch and gluten, with some other substances in smaller proportion. Thus, in 100 parts, there are—

Starch	68 parts
Gluten	24 "
Gummy sugar	5 "
Vegetable albumen	1·5 "

Stated more fully, it consists of starch, gluten, albumen, gelatin, oil, gum, cerealin, phosphates of lime and other phosphates, and water; but it is with the starch and gluten that the baker has chiefly to do.

Sir Humphrey Davy stated that wheat sown in autumn contains 77 per cent. of starch and 19 of gluten, while that sown in spring yields 70 of starch and 24 of gluten; and that the wheat of the south of Europe contains a larger proportion of gluten than that of the north. But these calculations are hardly reliable. Generally speaking, in every 100 lb. of good wheaten flour there exist from 62 to 68 lb. of starch and from 10 to 14 lb. of gluten, according to quality of the flour. The average may be taken as 65 lb. of starch and 11 lb. of gluten; while 14 lb. of water and 10 lb. of the other substances already mentioned make up the 100 lb. The flour of almost every other cereal, except wheat and rye, contains too little gluten, or gluten too weak, to enable it to be made into properly vesiculated bread.

When flour is made into a paste with water, the mixture is called dough, and when this is suffered to remain in a moderately warm place, it undergoes that partial and spontaneous decomposition which is called fermentation, and which, in order to distinguish it from other kinds, has been named the *panary* fermentation. During this process, a portion of the carbon and oxygen of the partially decomposed flour recombine, so as to form fixed air, or, more correctly, carbonic acid gas, the natural tendency of which to escape into the air is arrested in its progress through

the dough, by the adhesiveness of the gluten forming numerous cavities in it. It is thus that dough made of wheat-flour becomes equally vesiculated by the diffusion of small bubbles of carbonic acid gas throughout its substance, and makes a lighter and more digestible bread than that of oats or rye. This plan of fermentation would, however, not only require much time, but the dough is never quite free from putrescence and acidity, both of which are injurious to the flavour of the bread. To remedy these inconveniences, the process was formerly accelerated by adding to a mass of newly-made dough a small quantity of old dough in a state of strong fermentation, called *leaven*.

The invention of leavened bread was, perhaps, like many others, the result of accident. Its antiquity is doubtful, though the Chinese are credited with the knowledge of making leavened bread from wheaten flour nearly 2000 B.C. At all events the art was familiar to the Egyptians in the time of Moses. The secret afterwards became known to the Greeks, and through them to the Romans, who spread the invention far and wide in their campaigns. Baking became a profession at Rome in 170 B.C., and after the conquest of Macedon, 148 B.C., numbers of Greek bakers came to Rome and obtained special privileges, which resulted in the trade becoming a monopoly in their hands.

But though the use of leaven was an unquestionable improvement, still further progress has been made by the employment of a variety of ferments called *yeasts*, by which the fermentation of the dough is more rapidly and perfectly effected. The yeast of the Romans was

made by steeping bran or the waste of the mill in Levant wine for three days, rolling it into balls, and drying it in the sun. This was perhaps the first "patent yeast." English bakers used yeast in 1634. Brewers' yeast was at one time almost the only form known in this country, but the introduction of a variety of "patent" and other yeasts, which can be kept in stock, has to a great extent superseded it. Fifteen years ago, an attempt was made to dry brewers' yeast in a form which would keep, but it was only partially successful. More recently, however, a better method has been discovered of drying it and making it into cakes, which will remain good for a considerable period, and it is not unlikely that the new production will be extensively used by bakers. Among the substitutes for brewers' yeast may be mentioned the "patent" yeast prepared from an infusion of malt and hops; Vienna yeast, which is obtained from malted barley, maize, and rye ground together and infused in water for a few hours at a temperature of from 150° to 170°; and German yeast, which is the solid residue of the yeast produced by the fermentation of rye for making hollands. Bakers, however, for ordinary bread-making almost universally prepare a special "ferment" of boiled and mashed potatoes (called "fruit" in the trade), to which yeast, either patent or brewers' yeast, or a portion of each combined, and a little flour is added; but of this further mention will be made in describing the method of bread-making.

The importation of dried yeast from abroad is in-

creasing, the value of that imported in the first eleven months of 1874 being 365,149*l.* as against 341,078*l.* in the preceding year. But this increase may partly be accounted for by the increased demand for "fancy goods," the term applied in the trade to buns, cakes, &c. German yeast is quicker than any other yeast in its action, and costs considerably more than double the price of brewers' or patent yeast. Whether the action of yeast is to be explained on the fungoid theory, and the corpuscules viewed as "veritable plants," in accordance with the teachings of many eminent scientific men, I cannot discuss here; but certain it is that yeast, as produced in the making of beer and spirits, contains a large quantity of gluten obtained from the cereals used. It may therefore be practically viewed as gluten in a condition of change, and possessing the property, when coming into contact with the gluten of flour, of producing the same changes in it, and thus setting up the first stage of fermentation; and the yeast cells may be looked upon simply as vesicles of carbonic acid gas entangled in the elastic gluten.

A perfect vesiculation, however, of dough, and consequently of bread, can be effected by means of chemicals; but in all cases the dough rises by the action of carbonic acid gas. Bread thus produced is called *unfermented* bread. Carbonic acid in dough is generated by the action of an acid on bicarbonate of soda. Dr. Whiting's process, patented in 1836, was to mix carbonate of soda with the flour, and then to act upon it with a proper proportion of muriatic acid in the water. In 1845 the use of tartaric acid was

patented instead of muriatic; and the various preparations, called *baking powders*, are for the most part mixtures of tartaric acid and carbonate of soda in about equal proportions, with a little cheap farinaceous matter, such as rice flour, to give greater bulk, to which turmeric powder is added to impart a rich yellow tint. When these are mixed with flour and wetted, they effervesce, like a common Seidlitz powder, and so diffuse carbonic acid through the dough. *Phosphatic yeast* is a preparation of phosphoric acid and an alkaline carbonate. Other mixtures for the same purpose consist of bisulphate of potash, or alum, and carbonate of soda. Another process is that of Dr. Dauglish, patented in 1856 and 1857, by which also carbonic acid brings about the result required, and the well-known "Aërated Bread" is produced, to which I shall refer again. The same effect is brought about by mixing carbonate of soda with the flour in its dry state, and adding tartaric acid or weak hydrochloric acid to the water. But there are two objections to this process, viz. the uncertainty as to the uniform distribution of the chemicals, and the retention of the tartrate of soda in the bread. In all cases where carbonic acid is generated within the dough by processes other than that of fermentation, immediate baking is a primary necessity; for if not baked at once, the dough will soon fall and produce a heavy loaf.

Here it may be mentioned that potatoes are used in bread-making solely for the purpose of assisting fermentation, their efficacy for which arises from their richness in starch. Experience as to their value, more

than any ascertained chemical fact, has led to their employment by bakers, as the most suitable article for starting fermentation. The peculiarity, however, of the starch of potatoes when compared with that of flour, and the more complete bursting of the granules in the boiling to which they are subjected, have something to do with their ascertained value in the commencement of fermentation. Mealy potatoes are better than waxy ones. Salt is used not only for the flavour which it gives to the bread, but for the part that it takes in the process of fermentation. It helps to keep the gluten in a more compact form, and prevents it making too rapid changes in the starch. Hence when flour is old and the gluten more set, less salt is required, but more, when the flour is fresh and the gluten is apt to carry on its work too fast. Thus salt regulates fermentation; the yeast being the whip, and the salt the bridle in this process. Hence it follows, that neither ought to be used in greater quantities than are absolutely necessary.

The different chemical processes which take place may be thus briefly described. Some potatoes, a few pounds of flour, the requisite quantity of yeast at a temperature of 80° to 90°, being mixed together in the ferment tub, fermentation soon commences. The yeast attacks the gluten of the flour, and imparts to it the property which itself possesses of transforming starch into sugar; and this action progresses as fresh flour is added, till the gluten is coagulated and fermentation stopped by the heat of the oven. The sugar produced by the action of the yeast and gluten on the starch is

not exactly the same as that which is generally known by that name. It is not so sweet, and is called by chemists glucose or grape sugar. But the whole of the starch does not undergo this change; and while this formation of sugar is going on, portions of it are being transformed into carbonic acid gas, evolved from the glucose, which gas, struggling to liberate itself, is distributed more or less evenly through the whole mass of the dough. In addition to carbonic acid, the fermentation of the glucose generates alcohol, which by exposure to the atmospheric air involves the danger of acetic acid being formed. The object, therefore, of the baker should be to get his bread into the oven, as soon as his dough has obtained a sufficient supply of carbonic acid; or in other words, he must not let his fermentation proceed too far, for fear of his bread acquiring a sour taste. There is another chemical danger which besets the dough, namely, lactic fermentation—the same which occasions sourness in milk. It is probably owing to a weakness in the quality of the gluten (and perhaps an excess in quantity) and bad albumen, that this kind of fermentation is set up. Bread made from flour with bad gluten and albumen is very difficult to bake. The gluten does not get thoroughly coagulated, and a fresh fermentation commences, not from the action of the yeast, but from a spontaneous decomposition of the gluten and albumen. This probably is the origin of what is known as "ropy" bread.

Thus far the purely chemical aspect of fermentation. Let us now follow the baker through the process of

bread-making as it is practically carried out in an ordinary bakery, which, by the way, was well described by Dr. Colquhoun some forty years ago in his Essay on 'The Art of Baking Bread.'*

We will suppose that an ordinary "batch" of "set" bread is to be made from two sacks of flour, which will produce, say, about 184 loaves of 4 lb. each. The first thing is to prepare the ferment. For this, 14 lb. of good potatoes (or fruit), boiled and mashed, are put into the ferment tub. To these about 2 lb. of flour are added, or, in order to accelerate the starting of the ferment, are worked up with them in cold weather in the process of mashing. About two pails of water (called *liquor*) at a temperature of about 90° to 100°, according to the weather, and six quarts of "patent," or three pints of "thick" (i. e. ordinary brewers') yeast, are added, and the ferment is prepared. This is usually done at 10 A.M. when patent yeast is used, or three hours later when brewers' yeast, which is slower in its action, is employed; and the ferment is then left to stand till 6 P.M., when the more active work in the bakehouse may be said to begin. The next, or second stage, is the making or "stirring" of the *sponge*. The two sacks of flour, consisting of different kinds, properly mixed with a view to give colour, flavour, and strength to the bread, have already been lightly sifted into the trough, and the mass is "penned" back by the "pen-board" (or movable wooden partition) into about two-thirds of the length of the trough, the remaining third being an open space. Over this a large

* Vol. xxviii. of the 'Annals of Philosophy.'

strainer is placed, and the ferment poured through it into the trough, two pails of warm water being further poured through the strainer, which retains the peel of the potatoes. The pen-board is now removed, and about a third or more of the flour is incorporated with the ferment by the baker's hands and arms, a process which consumes about half an hour, and requires careful and skilful manipulation. The comparatively soft and "battery" mass is called the sponge. The pen-board is then replaced between the sponge and the remainder of the flour, and the trough covered with the lid. The sponge is left for the process of fermentation to go on for five or six hours, during which it "rises," and collapses to about two-thirds of the bulk to which it had expanded. About midnight the third stage of the process of bread-making is commenced by "breaking" the sponge, or, in other words, by incorporating the rest of the flour with it, and thus forming the whole mass of dough. For this purpose the remainder of the "liquor," making in all about 144 quarts to the two sacks of flour, is added with about 6 lb. of salt, according to the age of the flour, and the whole mass is thoroughly kneaded, a process similar to, but far more laborious than, that of "stirring" the sponge. It is at this point of the manufacture, that the full complement of workmen are required in the bakehouse. This completed, the lid of the trough is again replaced, and the dough, penned up into about two-thirds of its length, is allowed to remain for about two hours more, when (about 3 A.M.) it is "thrown out," "scaled off," and moulded into loaves for the oven.

To prevent the dough sticking to the baker's hands and arms, and to the lid of the trough on which it is moulded, and also to ensure the loaves separating more easily from each other when baked, a flour made from "revets," or bearded wheat (known technically as "cones"), or flour made from rice, or a combination of both, is used to dust the board and the moulded loaves. Rice flour, however, is discarded by most of the best bakers, so that there may be no "traces" of this on analysis; but the use of revet cones is almost indispensable in manipulating the dough. Revet flour is used simply because of its "roughness," which prevents its becoming incorporated with the dough. The moulded dough will be ready for the oven between four and five o'clock, and as the process of baking takes about one and a half hours, the batch, which we have been following through its three stages, will have completed its fourth between 6 and 7 A.M., when it is "drawn." The other batches will follow in succession at intervals of about two hours. In the process of baking much care is required, and a good workman will never forget that a properly heated oven will materially add to, or detract from, the appearance and value of the bread. The baking should be so managed, as to ensure the thorough heating of the loaf to the temperature of at least 212°, in order that the insoluble starch may be changed by the heat into soluble dextrine.

The *old* method of bread-making, as compared with that at present in vogue, consisted chiefly in the practice of the *quarter sponge* instead of a ferment, the

absence of potatoes in the process of fermentation, and partly in the absence of "patent" yeast. It has been displaced by the modern practice, mainly because of the greater expense in carrying it out, partly because the process consumed a longer time and involved more skill and care, but chiefly because stronger and consequently dearer flours were necessarily employed. Bad or even inferior flour was not capable of being manipulated by the older method; and the result was, that a better article in every way was produced than that now in ordinary consumption. Many good bakers of the present day regret that the old system has fallen into abeyance, and would be glad to see its revival. On behalf of the present method, however, it must be remembered that in supplying large centres of population with daily bread, the time employed in its manufacture is a considerable element of calculation, and further, that by it, a good loaf of bread, sufficiently wholesome and nutritious for all practical purposes, can be produced. A recurrence to the old method would involve an additional charge of from 1*d.* to 1½*d.* on every 4-lb. loaf.

But though our chief concern is with ordinary wheaten or baker's bread, it will be necessary to glance at some other varieties of bread found in bakers' shops. *Brown bread* is made from "whole" meal, which contains all parts of the wheat grain, from the husk or bran to the innermost kernel, and it is contended that this kind is the most wholesome, as the husk chiefly possesses the phosphates and other inorganic salts, which are necessary for the proper

growth and formation of the bones and teeth in the human body, and act also beneficially on the brain. These phosphates, with perhaps the exception of lime, are in much larger percentage in the branny parts of the wheat than in finely-dressed flour, only about one-third of the phosphoric acid belonging to the wheat being found in the flour from which our ordinary bread is made, while the other two-thirds are left in the pollard and bran. Years ago, brown bread was the staple food of the working classes in this country, but the arguments of chemists and dietists seem to have led to the general conviction that white bread, though of course dearer in itself, is after all the cheapest, because the most nutritious food for all classes. It has been stated, with a considerable show of reason, that though brown bread is more easily digested, in consequence partly of its being to a certain extent a laxative, it does not really supply the body with the desired phosphates, as the flakes of bran prevent the bread lying long enough in the stomach for all the constituents of nourishment, including the phosphates, to be abstracted. To remedy this objection, the bran has been reground by a special method, and the flour produced is known by the name of "Chapman's whole meal." The bread made from it does not cause the same mechanical irritation of the bowels as ordinary brown bread, and as the particles of the bran are more exposed to the gastric juices of the stomach, they have a better chance of appropriation. "Hart's Whole Meal Unfermented Bread" is another kind much used in London. As its name

implies, no yeast is employed in its manufacture, but chemicals, as above explained, are substituted in order to lighten it. This meal is the result of a process of "bruising" rather than grinding; and Dr. Edward Smith says that it contains indigestible vegetable fibre of the husk to the extent of nearly 12 per cent., which is nearly 10½ per cent. more than in "seconds" flour, while it replaces the more nutritious starch of the latter. When whole meal is used, the cerealine of the bran sets up a peculiar kind of fermentation, which gives to the bread a sweetish-sour taste, and a soft consistence, and partly accounts for its dark colour. To avoid this, M. Mège-Mouries recommends that 10 to 14 per cent. of the meal produced by his process of grinding should be kept apart from the 70 per cent. of white flour, and should not be added to the dough made from the latter, until it is well fermented and ready to be baked. In this manner from 80 to 82 per cent. of the farinaceous matter of wheat is realized, and a white loaf produced. This process is employed at the Scipion works in Paris, where over 5500 lb. of bread are made daily. Eminent medical authorities strongly recommend the different varieties of brown bread, while others, Dr. Edward Smith for instance, discourage their use. It is not within the province of this article to attempt to decide the question; but it may be added, that the facilities for making inferior brown bread are largely taken advantage of by second-class bakers. *Rye* bread is not now used to the same extent as formerly, though a large quantity is consumed on the Continent. When

made according to the formula of the Board of Agriculture of France (1795), it consists of one part of rice and four of rye, ground together and sifted in the usual manner. The meal is made into dough with yeast, and generally baked into long rolls. The bread is very dark, has a close texture, but is agreeable to the palate, and has the reputation of being very nutritious. It is certainly cheap, for it can be made at less than a penny per pound. It is alleged also by some, that a good pure brownish bread of simple wheat-meal, with an admixture of a fourth or fifth part of rye, would, for equal money value, give the labouring population a food more abundant and nutritious than that which they generally make use of as fine white bread. What is known by the term *fancy bread* in our shops includes the many varieties of cottage, "tin" loaves, rolls, twists, &c., which do not call for any special notice as regards their manufacture; the "strength" of the dough, the time of fermentation, and the celerity in baking being more or less the features of this branch of baking. Some fancy breads contain butter or lard, and in some, milk is said to be wholly or partially substituted for water. Fancy bread is not sold by weight, as is ordinary baker's bread. From an English point of view, *French and German* bread, as made in this country, would perhaps come within the designation of fancy bread. In the production of this bread, German yeast is generally used, in consequence of the quickness of its action, but the best bakers prefer ordinary brewers' yeast, believing that it imparts a desirable flavour. The great "lightness" of this

bread is owing to the "weak" dough (i. e. dough with a large quantity of water) employed, and the consequent ease with which it is raised by the generated gas. This is particularly the case with the long rolls; but more flour is used in making the cottage loaves, after the French and German fashion. The "stronger" the flour, the larger quantity of water it will take up, and hence the strongest and best flours, with an admixture of Hungarian flour, are generally used. The glazed appearance of a pure "Vienna" roll is caused by the steam introduced into the oven, which at the same time protects the crust. When steam is not used, the rolls are "painted" with water. The "rasped" French rolls are baked very quickly, and it is simply a necessity that the "black" should be removed by rasping. The taste for French and German bread seems to have been considerably on the increase of late years in London, where there are several bakers of this article doing a large business, one alone, M. Bonthron, using over thirty sacks of flour per week.

Another kind of bread which requires notice is the *aërated* bread, as manufactured since 1863 by the company formed for that purpose, which adopted the patents of Dr. Dauglish in their entirety. The feature of the process employed is the pumping of carbonic acid gas into the dough, as it is being made, and thus rendering it as light as when acted upon by ordinary fermentation. The process may be thus briefly described. There are two strong iron vessels, each capable of sustaining a pressure

of 120 lb. on the square inch, of which one is the "mixer," and the other the vessel containing water to be charged by compression into the gas. The mixer receives the flour, and being furnished with "arms," worked by machinery, is ready to mix it with the water. Water containing a proportion of common salt having been introduced into the vessel, is charged with the gas under a great pressure until a proper quantity has been absorbed. The communication is then opened between the two vessels, and the charged water is admitted, whilst at the same time the arms of the mixer are set in motion, and the water and flour are rapidly worked together. During this part of the process, the gas not actually in solution becomes liberated from the water and permeates the bread, whilst the prepared dough is forced out of the mixer and made into loaves for the oven. The whole process, including the baking, is completed in about an hour and a half—a most important feature; a greater proportion of bread is produced by it; the chemical constituents of the flour remain intact, and the bread is not acted upon by chemical decomposition. Moreover, as the dough runs down a trough into the tins in which it is baked, it is never once touched by the hand during the whole process. The eminence attained by Dr. Dauglish as an authority in bread making caused immense interest to be taken in the aërated bread, and a large body of the public fully believed that the question of bread making had been finally solved, and that they were delivered from the real or imaginary objections to ordinary bakers' bread. Many too of the

most eminent physicians, chemists, and scientific men of the day gave unhesitating testimony in favour of the new bread, and recommended it far and wide as more wholesome, digestible, and nutritious than fermented bread. A great number of shops were opened to supply the public, and it seemed not unlikely that the new-fashioned bread would eventually supersede the old; but the result was not in accordance with the anticipations formed. It would seem that very light bread, except in the form of French and German, is not suited to the English taste, which, generally speaking, prefers a more solid article; and it is probable also that the advantages of unfermented, as compared with fermented bread, were overstated. In fact, an imposing array of authorities might be brought forward in favour of the use of fermented bread, except in the case of some constitutions, on the very ground that the chemical action brought about is beneficial, and especially that the chemical change of part of the starch during the process of fermentation not only adds an agreeable flavour to the bread, but is actually an aid to digestion. I will only add that one of the latest authorities who have written on the subject of food * says, that although aërated bread is a wholesome and nutritious substance, he cannot allow that it is capable and worthy of supplanting fermented bread, which is at once "the most wholesome, digestible, palatable, and nutritious of all edible compounds." *Home-made bread* hardly comes within the scope of this article,

* Dr. Muter, 'Pharmaceutical and Medical Chemistry.'

nor would it be necessary to say more than that it is made on the same principles as ordinary bread. Indeed among the poor, baking at home has for years past been gradually going out, though in many of the Midland and Northern manufacturing towns the practice is prevalent, and even here the dough is frequently made at home and taken to the baker's. As a rule, it may be stated that bread cannot be made at home so well or so profitably as the baker can make it.

From the time that baking became a trade, bakers in almost all countries have produced different qualities of bread. Thus the Romans had six or seven varieties, from the coarse brown bread (*panis ater*) to the whitest (*panis candidus* or *primarius*). In this country, in the thirteenth century, there were three qualities regulated by law: the wastal (fine wheaten), cocket bread (seconds), and *Bread of tourte* (brown bread). The *Liber Albus*, as regards the Assize of Bread in the city of London, refers to many more varieties. Of ordinary breads, bakers produce two, best wheaten and household, though it is not in many shops that we find them selling both. A baker, generally speaking, makes but one kind, depending on the quality of the flours. Thus the high or full price baker uses a larger proportion of the "higher marks" or more expensive flours, than a medium-price baker, while the "cutting" baker uses inferior flour, and has recourse more or less to adulteration. But practically, it is very difficult to draw an exact line between the best wheaten and household bread, and very often a high-price baker does not produce a bit better bread

than his neighbour, because the latter sells for ready money, while the former frequently gives long credit. The finest white flour is derived from the central parts of the wheat kernel, and costs more in the process of preparation. But good "household" flour, from the fact that it contains more of the outer skins of the kernel, and consequently more of certain chemical constituents of wheat, makes even better and more nutritious bread than the other. For a good loaf we depend on the honesty and skill of both miller and baker, but primarily of the former, who grinds great varieties of wheat from all parts of the world, differing in their chemical value and adaptability for bread making. The miller therefore blends flours as the wine grower does sherries and clarets, as each contains more or less of the required constituents, such as starch and gluten. Thus the art of the miller offers considerable scope for intelligence and knowledge. Though the baker to a great extent depends on the miller, he also acts on his own knowledge, and will often combine the blends of the miller or make original blends for himself, which by experience he has found to answer well. In the ordinary trade there are three kinds of flours, viz. "whites," "households," and "seconds;" the two first being known in most provincial districts as "superfines" and "fines." To these may be added "country flour," which represents the product of wheat grown on weak soils in some of our eastern counties and elsewhere; and by second-class bakers in a general way, "whites" are used to give colour to bread, and "households" to give

strength and flavour. A sack of flour weighs 280 lb., and according to its quality will produce from eighty-eight to ninety-four loaves of 4 lb. each; probably the average number made by good bakers would not exceed ninety.

According to Dr. Edward Smith, the ultimate chemical composition of bread made from good "seconds" flour is, besides oxygen and hydrogen, per cent.:

Carbon	28·5
Nitrogen	1·29

And the proximate elements in 100 parts are:

Water	37
Albuminous and other allied substances	8·1
Starch	47·4
Sugar	3·6
Fat	1·6
Salts	2·3

A good loaf should show *kindness* of structure; i.e. it should not be chaffy, flaky, or sodden; and it should be sweet to the palate and the smell. It is most digestible the day after it is baked.

As it is probable that the health and vigour of the inhabitants of temperate climes are more attributable to the use of wheaten bread than to any other cause, it is of the utmost importance that our bread should be pure. Adulteration unfortunately has been widely adopted, both to increase bulk and improve appearances; and the following substances are alleged to have been more or less in use, viz. potatoes, rice, alum, pea-flour, plaster of Paris, sul-

phate of copper, pearl-ash, gypsum, pipe-clay, chalk, bone-dust, soap (which creates a strong fermentation and whitens bad flour), stone-flour, "which is made from Derbyshire stone," and the flour of a variety of cereals other than wheat. At the present time the only two adulterants worth notice are rice and alum; the former being used mainly to increase bulk, the latter to enable the baker to employ bad and "weak" flours, and yet present his loaves as "best wheaten bread." Potatoes, as before stated, are not now used for the purposes of adulteration, whatever may have been the case many years ago. Indeed they have been too dear for adulterating purposes. At the utmost a baker would not use more than 6 lb. of potatoes to a sack of flour, which makes 380 lb. of bread, or ninety-five 4-lb. loaves. During the potato famine of 1846–47 many bakers paid as much as 18*l.* per ton for their "fruit," which they certainly did not use as an adulterant. Rice and alum, then, are the materials with which we are chiefly concerned. The use of rice, which is generally first boiled and worked through a sieve, is a direct adulteration, both by the substance itself and by the additional weight of water that it will "take up." It is cheaper than "damaged" wheat and flour, which can often be bought for 1½*d.* per pound, or even less. Rice is not nearly so nutritious as wheat, as it consists almost exclusively of starch, and is relatively deficient in nitrogenous elements. There is therefore no defence to be made for its use in bread making. It can easily be detected by the microscope. Alum is used to make a present-

able loaf from bad flour, and its employment is openly mentioned and advocated by older authorities in the trade; but even with such a precedent, no well-informed or honest baker of the present time can attempt to employ it. From 10 to 30 or even 40 grains may be found in a 4-lb. loaf, and as it is known that 12 grains taken daily by a healthy adult will produce constipation, an average consumer of bread adulterated with alum must consequently suffer in health; for it must be remembered that the action of heat in the oven does not lessen the quantity of *alumina*, the base of alum, or diminish its astringency. Moreover, the action of alum interferes with the proper chemical process of fermentation, and thus renders the bread less nutritive, by causing the albuminous and other nitrogenous elements in it to be less amenable to the solvent action of the gastric juice. But since the passing of the Adulteration Act in 1872, great and unexpected difficulties have risen in its application, and in some convictions which have been obtained under it, considerable injustice has been done to bakers. In the first place, the detection of alum in bread has practically been found to be very difficult, the tests ordinarily used having in many cases given different results when applied by different analysts. The "Greenwich" and the "Edgeware" cases are well known, and in both the analysts employed by the prosecution and defence came to different conclusions, the one affirming that there were, and the other that there were not, traces of alum in the bread. In the second place, even when it may be allowed that there are traces of alum, it by no means follows that

there has been illegal adulteration. Traces of alum, detected by *qualitative* analysis, may be accounted for in a variety of ways. The millstones themselves, being made of Burr stone, have cavities in them which are generally filled up with burnt alum and grit; and consequently, as they wear down, may supply infinitesimal portions of alum to the flour. Aluminous soil in some instances get mixed up with the grain from the insect perforations and natural depressions. Again, alumina and sulphuric acid may often be found in small quantities in salt, which is always used in bread making. It is also alleged that certain soils will supply the grain of wheat with silica, arsenic, and alum in traceable quantities. On these grounds it has been urged, that a *qualitative* analysis should not be held sufficient to convict a baker, but that in any Adulteration Act a *quantitative* analysis should be required, and that no conviction should be recorded, unless the amount of alumina detected was in excess of what could exist, owing to one or more of the causes just named. Some persons go even farther than this, and maintain that it is better to use alum with deteriorated flour, than that such flour should be wasted altogether. Thus Dr. Edward Smith says, "If employed in very small proportions, it might be useful when the flour is of inferior quality, as the result of a cold or wet season or of sprouting, and in that proportion might not be injurious to health." The operation of the Act of 1872 (the Act of 1860 being practically inoperative), has certainly done some good, and partially restrained adulterant bakers; but its uncertainty of application,

and the injustice inflicted under it, were admitted by the Parliamentary Committee in 1874.

Bread making has been in this, as in many other countries, the subject of legislative or municipal interference from the earliest times. As long back as the reign of John (1203) there were "certain ordinances of the Assize of Bread," of which the chief justiciary and a baker, commissioned by the king, had the inspection. A statute of Henry III. (1266) regulated the price of bread by the price of wheat (irrespective of the price of flour) and the weight of the loaf was increased or diminished as the price of wheat rose or fell. The mode of "setting the assizes" and the whole procedure, including the principles of remuneration to the baker for the trouble, is set out in a most interesting manner in the *Liber Albus* of the City of London Corporation, from which also may be gathered the severe penalties sometimes inflicted on bakers, who either sold short weight or adulterated their bread. Matters seems to have remained substantially unchanged till the reign of Anne, when a statute was passed (1709), with a view to remedy some of the many defects in the existing regulations; but neither bakers nor consumers were satisfied, and complaints from both were frequent, mainly owing to the different and contradictory modes of "setting the assize" in different parts of the country. Both parties, it may be allowed, had substantial grievances; for the action of the law in various ways inflicted great injustice on honest tradesmen, and the price of bread, instead of being kept at a fair and equitable rate by the Assize,

was often unduly raised by it. After the whole matter had been thoroughly ventilated and discussed both in and out of Parliament, during the early part of the present century, the "Assize of Bread" was abolished in the metropolis by Act of Parliament in 1822 (3 Geo. IV. c. cvi.), throughout England and Scotland in 1836 (6 & 7 Will. iv. c. 37), and the measure was applied to Ireland in 1838 (Bread Act, Ireland, 1 Vict.). By the Act of 1836, which is still in force, bakers may make bread of any weight and size as they think fit, but they must sell it *by weight*. An exception is made in the case of French or *Fancy bread*, and which is not required to be sold by weight. Considerable difficulty has, however, risen up under this provision, as it is almost impossible to define what "Fancy" bread really is. From time to time bakers have been prosecuted for selling "cottage" and other loaves "separately" baked, otherwise than by weight: but though they have pleaded the exemption just stated, in many cases they have been convicted, on the ground that the mere shape of a loaf does not necessarily make it "Fancy" bread.

The provisions in the Act in reference to adulteration are still in force, but were modified by the Adulteration Acts of 1860 and 1872. The clause which enacted that all loaves made of mixed meal or flour should be marked with a large Roman M, seems to have practically fallen into abeyance soon after the passing of this Act; and it is even said that by reversing the position of a loaf so stamped, the public often mistook the M for a W, and considered the *latter letter* to signify Wheaten bread.

The result of removing the old and vexatious restrictions in reference to the making and price of bread, was practically to throw open the trade, and eventually to bring about severe competition, which, since the abolition of the Assize, has become greater. The introduction of "patent" yeast, and the small amount of skill and capital required, offer great facilities for the journeymen setting up for themselves; and many millers are themselves the real proprietors of shops, where their flour is used by the nominal masters who engage journeymen for the work, and are paid either so much per sack of flour which they make into bread, or for a given number of loaves.

The following tables will show the average prices of bread in various years:

QUARTERN LOAF = 4 lb. 5½ oz.

A.D.	Price. d.	A.D.	Price. d.
1735	5½	1800	17½
1745	4¾	1800 (for 4 weeks)	22½
1755	5	1805	12½
1765	7	1810	15½
1775	6½	1812 (Aug.)	21½
1785	6¼	1814	12½
1795	12¼	1820	11

THE 4-LB. LOAF (best), Full Price.

A.D.	Price. d.
1822	10
1825	11
1830	10½
1835	7
1840	9

THE 4-LB. LOAF (best), Full Price.

A.D.	Price, June.	Price, Dec.
	d.	d.
1845	7½	7½
1850	7	6½
1854	10	11
1855	11	10½
1856	11	10½
1857	9½	8½
1858	8	7
1859	8	7½
1860	8½	9
1861	9	9
1862	9	8
1863	8	7
1864	7	7
1865	7	8
1866	8½	9
1867	10	10½
1868	10	8
1869	7½	7½
1870	7½	8
1871	8½	8½
1872	9	9½
1873	9	9
1874	9	8
1875	7½	8½

From these prices, say for the last twenty-five years or so, 1½*d.* may be deducted, and we shall have about the price charged by the ordinary fair-dealing bakers. At the beginning of 1876 the maximum price of the 4-lb. loaf was about 8*d.*; ordinary bakers charged 6½*d.*, and low-priced bakers 5*d.*; but there was an article on sale in some shops as low as 4¾*d.*

It was thought by some that the abolition of the

Assize would diminish the number of bakers, and cause the trade to fall into the hands of capitalists. There has been a tendency in this direction in Scotland, but not so in England. Attempts have been made from time to time to establish great businesses, both by companies and individuals, and also on the co-operative principle; but with few exceptions, they have been failures. For instance, some thirty-five or forty years ago, a large concern was started by Mr. Ritchie in London, and carried on afterwards at Deptford by Messrs. T. and C. Kingsford, to supply shops in London. But after a time they declined this line of business, and confined themselves to the miller's trade. A considerable bakery was also established many years ago in Pimlico, where spirits were distilled from the steam which rose from the bread. Again, the League Bread Company, which started in 1846, failed to carry on business for more than about five years. Stephen's Machine Bread-making Company, formed in 1862, was thought likely by many scientific men to introduce a new era in the trade, but it was unsuccessful, while several attempts to establish co-operative bakeries in Birmingham and other centres of population have also failed. A recent effort to form a Flour and Bread Co-operative Supply Company, with mills and bakeries near London, met with little public support. There are, however, some moderately large bakeries at work in different parts of the kingdom; for instance, in Dublin and Belfast, where a single-handed baker uses perhaps 600 sacks of flour per week, or Paisley and Glasgow, where the

Crossmyloof Bakery probably gets through as many as 700 or 800 sacks per week. The majority of the "Contract" bakers (as they are called) for public institutions in the Metropolitan district and elsewhere do not possess establishments of their own, but "farm out" their contracts piecemeal to small bakers. The largest existing bakery is that of Mr. H. W. Nevill, whose bread is sold in every part of the Metropolitan district, and from its excellent quality commands a higher price than ordinary bakers' bread. The chief feature of Mr. Nevill's bakery is the use of hot-water ovens. Within the Metropolitan district, as recently included in his returns by the Registrar-General, and comprising the area of a circle whose radius is 15 miles from Charing Cross as its centre, and containing a population of over 4,000,000, there are in round numbers about 3500 master bakers, of whom perhaps 1200 are their own foremen, and take a share in the daily work of the bakehouse. Of the business done in these 3500 shops, it may be said that not in half-a-dozen establishments are over 100 sacks of flour used per week. The number of shops is also very small where over 50 sacks are used, perhaps not 100 in all; a considerable number range, say from 20 to 30, but the great majority only bake from 8 to 12.

Biscuits.

The manufacture of Biscuits has of late years, in this country, been developed into so large an industry, that it necessarily finds a place in connection with an

article on Bread. It is somewhat strange, as Mr. G. Phillips Bevan remarks in his Report on the Food Products of the Vienna Exhibition of 1873, that German, and especially French, bakers and confectioners have paid but little attention to biscuit making. At Vienna the display of the almost infinite varieties of English biscuits, which are sent in large quantities to almost every part of the known world, attracted special attention among foreigners interested in the matter of prepared food products.

Biscuits are for the most part unleavened, and when simply made of meal or flour and water, with or without a very slight addition of butter, are called hard or *captains'* biscuits. The biscuits produced in enormous quantities in our dockyards are of the simplest form; but the machinery employed is wonderfully contrived with a view to economy and expedition. *Fancy biscuits* are generally made of the finest qualities of flour, and of special "strength." The process of preparation is far more simple than that of bread, since it is only needful to mix well the flour with the water or milk, and to add salt, butter, sugar, and any other flavouring or colouring matter that may be desired, until a dough of sufficient consistency shall have been produced. This is collected in receivers, and put through a series of rollers to be reduced to the required thickness, or worked by the hand, after which it is cut by hand "cutters," or machines, into the requisite sizes and forms, and is either baked on tins in ordinary ovens or on "wires," or passed through ovens on an endless band until sufficiently baked. The biscuits are then

left to dry. The ordinary kinds of biscuits are, according to Dr. Edward Smith and other dietetic authorities, very wholesome, and contain a much larger proportion of nutriment than the same weight of bread. They might therefore form a much larger element than is now the case in household consumption. But, at the same time, it must be remembered that they are not easy of digestion unless thoroughly disintegrated, and even then, there should be plenty of fluid in the stomach to ensure their rapid solution. Those lightened by means of eggs, sugar, and butter, are more digestible than plain ones, and still more so when they are vesiculated and puffed up by means of a small quantity of carbonate of ammonia, as in the case of *cracknells* and *Victoria* biscuits. But the use of a chemical often imparts an unpleasant taste and smell to the article, and is not adopted by the best biscuit makers. All biscuits, and especially "fancy" biscuits, should be kept as much as possible from atmospheric air. If packed in air-tight cases and kept dry, they will resist atmospheric changes for years.

The biscuit-making manufactories of Messrs. Huntley and Palmer, of Reading, and of Messrs. Peek, Frean, and Co., of London, are the largest in this country, and indeed in the world. The former was established as a wholesale manufactory about thirty-three years ago, and may be truly said to have made a cosmopolitan reputation. To attempt a description of the buildings, which cover many acres, and of the machinery and processes, would be impossible in a limited space. So well worthy of a visit are they, that, among other important

manufactories, the Japanese Ambassadors when in this country, a few years ago, were taken to Messrs. Huntley and Palmer's establishment, and after carefully going through every department, expressed their highest admiration of all they saw. Wherever manual labour can be saved it is done, and a pair of magnificent engines of 120 horse-power and other smaller engines drive the various machines used. Order and cleanliness are features throughout the whole establishment; and a large reading-room and library is provided for the work-people. To give some idea of the enormous business of the firm, it may be stated that over 2500 hands are employed, and more than 1000 sacks of flour are weekly converted into cakes and biscuits, while the milk, butter, sugar, and eggs used would be sufficient to supply the population of a considerable town. The varieties of biscuits produced may, in round numbers, be put at over 150; and two vans are employed the whole day bringing in "returned empties" from the railway station. The manufactory of Messrs. Peek, Frean, and Co., near Southwark Park, is very similar to that of Messrs. Huntley and Palmer, and scarcely inferior to it in any respect. It stands on about three acres of ground, and the number of hands employed is from 1500 to 2000. The chief feature, however, of Messrs. Peek, Frean, and Co.'s business is the manufacture of "hard" biscuits, as distinguished from "fancy" biscuits. But while the products of these firms are most highly to be commended, it is but fair to most of the other establishments, to say that their biscuits in every

variety are quite equal to them; indeed, in the opinion of many good judges, several well-known biscuit makers turn out even a superior article to those produced by the above-mentioned firms. In London, for instance, the biscuits made by such bakers as Leman, Hill, Purcell, and Johnston, are as good in every respect as it is possible to make them.

There are hardly any associations connected with the manufacture of bread which call for notice. The Bakers' Company, which was incorporated in 1307, does little or nothing in connection with the bakery trade, being chiefly concerned, like most of the City of London companies, with the administration of its charities and social enjoyment. The Master Bakers' Protection Society was established in 1868, the objects of the Society being to watch and suggest legislation in reference to the trade, to work legitimately for the repeal or modification of Acts of Parliament which may injuriously and unfairly affect it, and to defend members of the Association, when in its opinion they are being unfairly dealt with. On the other hand, it does not lend itself to defend those who have transgressed the law deliberately, and its general aim is to elevate and purify the trade.

The above remarks, though they have extended to a far greater length than was anticipated, cannot pretend to have exhausted the subject treated of. To deal fully with it would require a volume. Considering its magnitude and interest, it is somewhat strange that so little, comparatively speaking, has been written on the subject. Among the works which may be consulted

with profit may be mentioned Mr. A. Edlin's 'Treatise on the Art of Bread Making' (1805); Dr. Colquhoun's treatise in the 'Annals of Philosophy'; William Playfair's pamphlet on the 'Prices of Wheat, Flour, and Bread, in connection with Wages' (1822); Mr. T. K. Callard's pamphlet on 'Fermentation' (Stock, Paternoster Row, 1874); 'Treatises on Food,' such as those by Doctors Letheby and Edward Smith; and Mr. Tremenheere's 'Parliamentary Report of 1862,' which is practically the most valuable contribution of all to the literature of bread-making.

SUGAR REFINING.

By C. Haughton Gill (late Assist. Exam. in Chemistry, Univ. of London).

Sugar in various forms has been known from a very early date, if we may trust to such passing allusions as those of Herodotus, who speaks of "honey made by the hands of man," and of Nearchus, who mentions a reed which yields honey without bees. But it is not till the time of Nero that any distinct and descriptive mention of sugar is made, and then only as a curiosity or a medicine.

Dr. W. Falconer, in his "Sketch of the History of Sugar in Early Times and through the Middle Ages,"* from which I draw my information, says that Albertus Agnensis (A.D. 1108), one of the historians of the Crusades, describes the sugar cane as met with by the Crusaders in Syria, where it was found in great quantity about Tripoli, under the name of Zucra. "This plant is cultivated with great labour of the husbandman every year. At the time of harvest they bruise it when ripe in mortars, and set by the strained juice in vessels till it is concreted in the form of snow or white salt. This, when scraped, they mix

* 'Memoirs of the Literary and Philosophical Society of Manchester,' vol. iv. 1796.

with bread, or rub it with water, and take it as pottage, and it is to them more wholesome and pleasing than the honey of bees." Another of the historians quoted, Jacobus de Vitriaco (1124), says that in Syria reeds grow that are full of honey, by which he understands a sweet juice which, extracted by the pressure of a screw engine and concreted by fire, becomes sugar. About the date 1170, Hugo Falcandus speaks of sugar being produced in Sicily in great quantities, and from this time the culture of the cane and the manufacture of sugar seem to have rapidly extended to the southern coasts of Europe; thence to Madeira and the Canaries, and at a subsequent period to the West Indies (about A.D. 1500). In 1747, Margraf, a German chemist, discovered the presence of sugar in the "beet," but it was not till 1796 that sugar was practically made from this root in any quantity. Since then the industry has progressed in a marvellously rapid manner on the continent of Europe, so that at present the annual production of sugar from this source amounts to more than 1,000,000 tons.

As the properties of sugar, taken as a whole, regulate its behaviour under the influence of the processes to which it is subjected in manufacture and refining, it is advisable to consider some of them pretty closely, before treating of the various methods employed for getting the pure material from the vegetable juices in which it is originally found, and for purifying the crude product first obtained.

Sugar is a transparent, crystallizable, very soluble, solid, possessed of a characteristic sweet taste, and

composed of the three elements carbon, hydrogen, and oxygen, in these proportions:

Carbon	42·11 per cent., or	12 atoms
Hydrogen ..	6·43	„	22 „
Oxygen ..	51·46	„	11 „

Its formula $C_{12}H_{22}O_{11}$* shows that hydrogen and oxygen are contained in it in the same proportions as in water, but nevertheless water, as such, does not exist in the crystals, which are anhydrous (free from water of crystallization).

Sugar, as is well known, is exceedingly soluble in water, which at ordinary temperatures is capable of taking up about twice its own weight to form a viscid liquid of specific gravity 1·333. This very great increase of density points to a ready means of determining the quantity of sugar in a solution of that substance, when other bodies are absent. Accordingly tables have been constructed, showing the proportions of sugar and water corresponding to all densities between 1·000 and 1·333. The best and fullest of these is that published by *Mategezeck*, in the 'Zeitschrift des Vereins für Rüben Zucker Industrie,' vols. xv. and xx., but which has not, unfortunately, been reproduced in this country.

As illustrating the degree to which the densities of sugar solutions vary with the percentage of sugar, the following table is given.

* C = 12, O = 16, Water = H_2O.

Per cent. Sugar by weight.	Degree of Baumé's Hydrometer.	Specific Gravity.	Per cent. Sugar by weight.	Degree of Baumé's Hydrometer.	Specific Gravity.
1	0·56	1·0039	37	20·3	1·1641
2	1·11	·0078	38	20·84	·1692
3	1·67	·0117	39	21·37	·1743
4	2·23	·0157	40	21·91	·1794
5	2·78	·0197	41	22·44	·1846
6	3·34	·0237	42	22·97	·1898
7	3·89	·0287	43	23·5	·1950
8	4·45	·0319	44	24·03	·2003
9	5·00	·0360	45	24·56	·2056
10	5·56	·0401	46	25·09	·2110
11	6·11	·0443	47	25·62	·2164
12	6·66	·0485	48	26·14	·2218
13	7·22	·0528	49	26·67	·2273
14	7·77	·0570	50	27·19	·2328
15	8·32	·0613	51	27·71	·2383
16	8·87	·0657	52	28·24	·2439
17	9·42	·0700	53	28·75	·2495
18	9·97	·0744	54	29·27	·2552
19	10·52	·0787	55	29·79	·2609
20	11·07	·0833	56	30·31	·2666
21	11·62	·0878	57	30·82	·2724
22	12·17	·0923	58	31·34	·2782
23	12·72	·0969	59	31·85	·2840
24	13·26	·1015	60	32·36	·2899
25	13·81	·1061	61	32·87	·2958
26	14·35	·1107	62	33·38	·3018
27	14·9	·1154	63	33·89	·3078
28	15·44	·1201	64	34·40	·3138
29	15·99	·1249	65	34·90	·3199
30	16·53	·1297	66	35·40	·3260
31	17·07	·1345	67	35·90	·3322
32	17·61	·1393	68	36·41	·3384
33	18·15	·1442	69	36·91	·3446
34	18·69	·1491	70	37·40	·3509
35	19·23	·1541	71	37·90	·3572
36	19·77	·1591	72	38·39	·3636

As most other soluble bodies, e. g. salt, likewise give solutions which are denser than water, it is obvious

that when they are present, the density of a given liquid will afford no trustworthy guide to the quantity of sugar in solution, and other means must be adopted to determine its amount. These methods are, however, too technical to find place here. Soluble as sugar is in cold water, it is still more so in hot, and indeed at the temperature of boiling water, 212° F. or 100° C., it is soluble in almost all proportions; but, as in other similar cases, the hot saturated solution deposits on cooling that quantity which it had taken up in virtue of its high temperature, leaving in solution only so much as the water present would have dissolved without the aid of heat. This, though a very simple matter, is the fundamental fact on which the recovery of sugar from its solutions is based, for if we take a weak solution of sugar and boil off some of the water, so that what remains is less than would have sufficed, when cold, to dissolve all the sugar present, then, on cooling, the sugar which has remained in solution in virtue of the high temperature, will deposit more or less quickly in the form of solid crystals.

For every temperature up to the boiling point of water, there is a point of saturation, i. e. a point at which the water present is not capable of dissolving any more sugar; therefore if the water of a solution of that body be evaporated off at say 150° F., a point will be reached at which sugar will begin to separate out in the solid form, because the water left is no longer sufficient to keep it all in solution at that temperature; and on continuing the evaporation, more and more sugar will separate, leaving always the remaining

solution of the same degree of strength, i. e. saturated at that temperature (150° F.).

But sugar, like other soluble solids, is capable and even apt to form supersaturated solutions when a saturated, hot, clean, solution is allowed to cool without being disturbed in a manner that is capable of producing the commencement of crystallization. The solution will then remain free from solid deposit when cold, though the sugar in solution is far more than the water would have dissolved at the same temperature, if simply shaken up with an excess of the solid. This state of supersaturation may obtain at any temperature below the boiling point of water, and may be destroyed in a variety of ways, the introduction of ready-formed crystals of sugar being the most obvious, though the addition of small quantities of fresh unboiled solutions of sugar (containing dissolved air and dust particles) is most practised.

On disturbing the state of unstable equilibrium of the solution, the sugar in excess of the proper quantity for the temperature separates very quickly, and the remaining solution then contains only its normal proportion. The well-known experiment with sulphate of soda will serve as a very perfect illustration of the facts relating to the supersaturation of sugar solutions.

The crystals formed either by the cooling or the evaporation of a hot saturated solution of sugar will be the larger and more perfect, the more slowly they are deposited; when they separate very quickly, they are always small and confused.

When other bodies are present in solution with sugar, they may interfere with the crystallization of that substance in either of two ways. They may act chemically on it and actually change it into something else, or they may render the liquid so viscid, that its particles are unable to draw together and arrange themselves, and if in very large proportion, they may even require so much water to keep them in solution, that the liquid cannot be concentrated sufficiently to pass the saturation point of the sugar present without losing its fluidity altogether.

Among bodies of the first class I may mention all strong acids, which even in small quantity possess the property of converting sugar (cane sugar) into two distinct but similar substances—dextrose, or "grape sugar," and levulose, or "fruit sugar"—when heated with it, or even allowed to remain in contact for some time at ordinary temperatures.

Also in this class must be included the substances known as "ferments," which are for the most part minute organisms similar to the common yeast plant; these also convert sugar into a mixture of dextrose and levulose with great rapidity at ordinary temperatures.

Again, many, and indeed most, of the alkaline salts, such as chlorides, sulphates, nitrates, acetates, &c., of potassium and sodium, combine with sugar to form new bodies, which either do not crystallize at all, or which crystallize with such extreme slowness and difficulty, that for practical manufacturing purposes they may be said not to do so.

These uncrystallizable saline compounds and the uncrystallizable mixture of dextrose and levulose, together with gummy, albuminous, and gelatinous substances derived from the plant juices brought into work, constitute the second class of bodies noted above as interfering with the crystallization of sugar from its solution. The members of the first class prevent the crystallization entirely, but those of the second only hinder it more or less, unless they be present in very large proportion.

Heat alone produces an alteration in the structure of sugar, even when in solution, if it be high and long continued; changing it into a mixture of dark-coloured uncrystallizable substances of almost unknown composition. This injurious action is greatly accelerated by the presence of already altered sugar or of saline or albuminous bodies. Consequently a vegetable juice containing sugar will submit to greater alteration during evaporation than a solution of pure sugar of the same strength under similar circumstances.

Though sugar is so sensible to the action of acids that heating it for a few minutes with a mere trace of sulphuric or hydrochloric acid is sufficient to convert most of it into dextrose and levulose, it withstands the action of alkalies such as potash or lime most completely, and is, indeed, far more stable in their presence, resisting the action of heat and ferments better, even than when quite pure. This, as will be seen, is a fact, of which important advantage is taken in the manufacture of sugar from the "beet."

Sugar which has become converted into a mixture

of dextrose and levulose, or *inverted*, as it is more commonly called, is, on the contrary, rapidly and completely changed into a mixture of various dark-coloured compounds by the action of alkalies and heat; a fact which it is necessary to bear in mind, when considering the application of certain processes of purification applied to sugary liquids.

Though the manufacture of sugar from either "cane" or "beet" can hardly be called a British industry (since there is but one factory in England,* and even that is not at present working), it is still necessary to give a slight sketch of the processes employed in obtaining the raw material on which the refiner works.

Manufacture of Cane Sugar.—The canes, cut when ripe, are carried to the mill and there passed through a series of three rollers, so arranged that the canes are drawn in between one pair, and out between another pair formed of one of the first rollers and another placed so close to it, that the first crushing is followed by a powerful squeezing. The juice, as it runs from the crushed cane, is caught in a trough and run off to a large tank called the clarifier; in this it is neutralized by lime (tempered), and heated till the scum which rises to the top begins to crack. The fire is then withdrawn (or steam turned off, if it be a steam-heated apparatus), and the clear liquor left below the scum run into the first of a row of copper pans, called *teaches*, heated by one fire at the end of the flue over

* Belonging to Mr. Duncan, of London, and situated at Lavenham.

which they are set, where it is boiled till it is concentrated to a certain degree, and then ladled into the next teach nearer the fire. Freshly-clarified juice is run into the teach just emptied, and the boiling continued. As the juice gets more concentrated, it is continually passed into smaller and smaller coppers (being skimmed all the time), till it arrives at the end one, in which it is concentrated to the "proof" point, i. e. to such a degree that the workman sees, and feels, by its viscidity that it will crystallize on cooling. The dark charred mass is then transferred to *coolers* and allowed to stand till *grained*, i. e. till as much sugar has crystallized out, as is sufficient to leave the remaining liquid only just saturated with sugar at the lower temperature. The magma of crystals and dark syrup is then put into casks having holes pierced in their bottoms, and allowed to stand till syrup ceases to drain away. The syrup is either re-boiled to make a lower quality sugar, or is at once sent to the rum distiller. The sugar so obtained consists of grains of nearly pure sugar coated on their surface with a film of the dark syrup, and generally contains some mechanical impurities, such as sand, vegetable fibre, &c.

The wasteful and unscientific mode of work just described in outline is still unhappily the one most largely in use, though here and there—notably in the French colonies—improved methods are employed with correspondingly good results.

Manufacture of Beet Sugar.—There are many methods of winning sugar from the "beet," but the

differences are mere matters of detail, except as regards the extraction of the juice.

The oldest and still most general method is to rasp the root to a fine pulp, wrap this in coarse woollen cloths, and submit it to the action of a hydraulic press. Sometimes the pulp is thrown into a centrifugal machine and the juice expelled from the mass by this means, water being added to wash the partly-dried residue.

The other principal method of extracting the juice—the so-called diffusion process—consists in slicing the roots up into strips about four inches long by half an inch wide and about a quarter of an inch thick, and submitting these to a systematic soaking, the portion of water which has been allowed to lie on one lot of the slices, and which has taken up some sugar, being allowed to run on to a fresh lot while its place is taken by pure water, and so on for four to six changes, each liquor continually going on to a portion of root which has been less washed out than that which it leaves. The sugar contained within the walls of the unbroken cells of the plant gradually passes out, by the process known by the name of *diffusion*, into water on the outside of the cells, until the strength of the sugar solution left in them is equal to that outside. A little consideration will show that, this being the case, the process described will result in leaving the cells nearly freed from sugar, and in obtaining a solution somewhat weaker than that originally contained in them. As bodies like albumen and gum are incapable

of diffusing, this method yields a juice remarkably free from these objectionable impurities.

The juice, when obtained, is passed into vessels which can be heated by steam, and is there mixed with a quantity of lime, varying from one-half to 3 lb. for each 100 lb. of roots operated on; the temperature is then raised till the scum cracks (defecation), the clear yellow liquor is drawn off into another tank, and carbonic acid gas (taken from the top of a lime-kiln) is pumped into it through a perforated worm, till nearly all the lime in solution has been precipitated in the form of insoluble carbonate of lime (carbonation). The defecation precipitates many of the vegetable bodies accompanying the sugar in the juice, and the carbonate of lime, when precipitated, carries down others with it, including some colouring matter. The clear "thin" juice is then passed through animal charcoal to further purify and decolorize it, and is then boiled down, to about 20° Baumé, in a partial vacuum, and is then again passed through fresh animal charcoal, and finally concentrated to crystallizing point in an ordinary vacuum pan. From the boiled mass the crystals are separated by the aid of the centrifugal machine, as described farther on under the head of Refining. The syrup yields a second and then a third crop of crystals, each more impure than the preceding. Raw cane sugar, if not too dirty, can be consumed directly, since the adhering syrup has a pleasant flavour, but raw beet is quite uneatable, and has a strong, unpleasant odour.

STATISTICS.

The estimated sugar production of the world, not reckoning the quantity consumed in China, India, South America, and other countries where no accounts are published, but including the exports from those countries, was in

1867	2,291,000 tons
1873	3,278,000 „

of which the beetroot sugar was in

1867	650,000 tons
1873	1,110,000 „

The extraordinary rapidity with which the manufacture of sugar from the beet has progressed is strikingly shown, if we go a few years back. In

1853 the total production	of the sugar	was	200,000 tons
1863	„	„	452,000 „
1867	„	„	650,000 „
1872	„	„	1,142,000 „

This growth has been caused, no doubt in part, by fiscal favour, and so far is artificial, but is far more due to the great degree of skill and science employed.

The countries which produce the enormous total weight of sugar here indicated, contribute in nearly the following proportions:

CANE SUGAR.

Cuba	600,000 tons
The other West Indian Colonies	250,000 "
Java and Sumatra	170,000 "
China	140,000 "
French Colonies in America and Africa	120,000 "
Brazil	100,000 "
Mauritius	80,000 "
British Guiana	80,000 "
Porto Rico	90,000 "
Manilla	60,000 "
Mexico	35,000 "
Egypt	Large and growing.

BEET SUGAR.

France	280,000 tons
Germany	260,000 "
Austria and Hungary	180,000 "
Russia and Poland	130,000 "
Belgium	50,000 "
Holland and other countries ..	17,000 "

SUGAR REFINING.

The object of the sugar refiner is to render fit for consumption that portion of the "raw sugar" which, owing to uncleanly and defective processes employed in its manufacture, cannot be used as food without further preparation. In other words, sugar refining is the freeing sugar from more or less of the impurities which accompany it on its first production from the cane or beet.

As pointed out in the preliminary remarks, crystallization is the chief process employed in effecting the

total separation of pure sugar from the other bodies which may be associated with it, but as some of these impurities, such as the colouring matter always present, would necessitate many successive crystallizations to effect their removal, it is found necessary to adopt special methods for getting rid of them before resorting to the crystallization, which is to leave the sugar in a state fit for consumption.

The operations of the refiner are essentially these:

First.—To dissolve the raw sugar in hot water in such proportions, that the solution shows a "thickness" of 27°–30° of Baumé's hydrometer.

Second.—To pass the solution so made through cotton bags to filter off solid impurities, sand, chips of wood, cane, &c.

Third.—To allow the still hot liquor to filter slowly through a deep bed of animal charcoal (called char), to remove colour and some other impurities.

Fourth.—To concentrate the now decolorized liquor by boiling off more or less of its water in a vacuum pan, till crystals have formed in proper quantity.

Fifth.—To separate the crystals more or less completely from adhering mother-liquor by some appropriate process.

The first operation, technically called "melting" or "blowing-up," generally takes place on one of the highest floors of the melting house. The sugar is emptied out of the casks or bags in which it is received, into round iron tanks, capable of holding three to six tons, and a proportionate quantity of water (equal to

about half the weight of the sugar), and dissolved by the aid of heat and agitation. In some refineries the heating is effected by passing steam through coils of closed copper tube, immersed in the mixture of sugar and water (close steam heating), while in others steam is directly injected into the liquid through perforations in a single turn of tube (open steam). In either case the sugar and water are kept in motion by some simple stirring gear, driven from a shaft passing over the line of *blow-ups*, until all the sugar is melted, when the workman dips out a portion of the liquor and "gauges" it by a Baumé's hydrometer. If the "thickness" is found to be above or below that required (27°–30° B.), he adds more sugar or more water as the case may be, and then brings the whole up to the temperature required, by continuing the admission of steam. The temperature of the liquor when finished, so far, varies in different refineries between 170° F. and 214° F. Certain low-class cane sugars, especially those obtained from the East Indies, when so melted with water alone, give solutions which filter with great difficulty, owing to their containing a quantity of fluffy material, which chokes the pores of the bags. In such cases some blood or other form of albumen is added to the mixture after the sugar is melted, but before the temperature has risen to 160° F.; when this point is reached, the albumen begins to coagulate and form a meshwork of filaments, which entangle the floating particles and cause them to clot together and rise to the surface as scum.

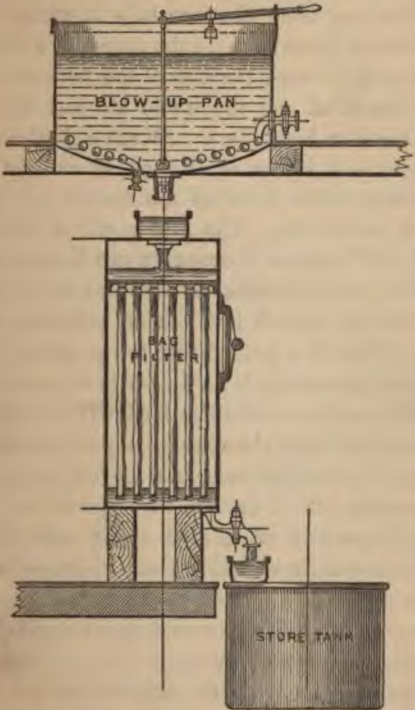
Sometimes, but not often, the sugar is melted in

vacuo, to secure the advantage of violent boiling (at a low temperature) and consequent thorough stirring up and rapid solution of the sugar.

The next stage is to filter the solution so made. For this purpose the liquor is allowed to run from the blow-up into a number of twilled cotton bags, about 2 feet wide by 5 feet long, each drawn into a coarse "sheath" of hemp, which prevents its expanding when filled with liquor, and so secures the advantage of a large filtering surface without the waste of space which would result from all being set far enough apart to assume their proper size. These filter bags with their sheaths have each a "bell" tied into their mouths, and are fixed about 6 inches apart in a plate of iron forming the top of the filter case and the bottom of the filter head, by screwing the small end of the "bell" (which resembles a funnel) into corresponding holes. The liquor, as it runs through the bags, falls into the bottom of the case in which the latter are hung, and runs thence into store tanks from which it is passed as required to the

Char Cisterns.—These are cylinders of cast or wrought iron of from 5 feet diameter and 15 feet depth to 8 feet by 40, and holding from 8 to 60 tons of animal charcoal. At an inch or two from the bottom, there is a perforated false bottom on which a blanket is spread, and immediately over this a man-hole in the side, for the purpose of removing the char when "spent." At the top there is another man-hole, which is closed when the cistern is in use, for the introduction of fresh char, and a pipe in connection with various cocks for the

admission of liquor, water, &c. A number of such cisterns, which varies according to the size of the refinery, from a dozen to fifty or sixty, are conveniently arranged



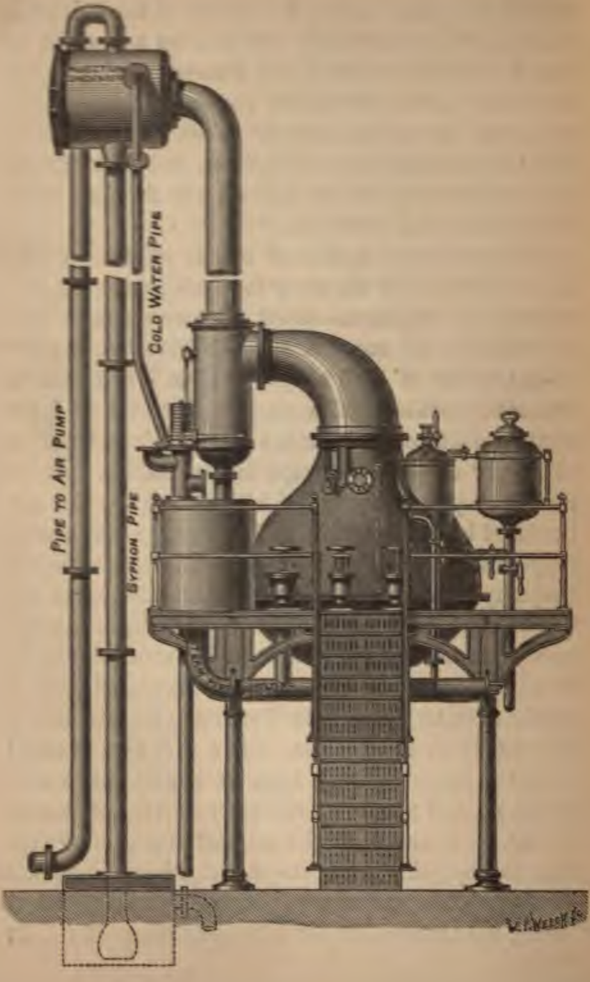
below the level of the raw liquor tanks, and communicate by pipes from their lowest part with a series of troughs, which in their turn discharge any liquor

turned into them into a number of tanks, from which the vacuum pans are fed. The cistern is filled up with animal charcoal in grains about the size of those in fine cannon or blasting powder, to within 8 inches or a foot of the top, when the man-hole is made fast, and the raw liquor turned on. In the course of a few hours, liquor begins to come through at the bottom, the cock is then turned off and the whole allowed to stand at rest for three or four hours. At the end of that time the decolorized liquor is allowed to run off slowly into a tank, while more of the brown raw liquor is admitted at the top. The first portions which come through are the most thoroughly decolorized, and are allowed to run by themselves into one tank, while the later ones are turned into others, according to their colour. When it is judged that the power of the char is sufficiently exhausted, the liquor is turned off at the top and hot water admitted to force out the solution of sugar, and to wash the char as a preliminary to re-burning it for further use. As the liquor and water mix to some extent during this operation, there is always a quantity of diluted sugar solution made, which, owing to its cloudiness and richness in all impurities, requires to be treated apart from the stronger and purer liquor. These char waters constitute one of the refiners' great difficulties.

The sugar liquor, i. e. the solution of raw sugar in water, contains, besides sugar, colouring matters of various kinds, gummy and albuminous bodies, and compounds of potash, soda, and lime, with various organic and inorganic acids. During its passage

through the char, nearly the whole of the colouring matter and a considerable but varying proportion of the other bodies indicated are absorbed, owing to the as yet but little understood power of porous forms of carbon to remove various substances from solution and attach them to themselves, just as cotton or wool will remove certain colours and fix them when immersed in their solutions.

The next operation, that of boiling off the water so as to cause some of the sugar to crystallize out, is performed in an apparatus called a vacuum pan, which, as shown in the annexed cut, is a globular, or pear-shaped vessel of hard copper of from 7 to 14 feet in diameter, provided with a steam jacket over its lower portion, and three to six large and long spirals, or rather helices, of copper steam-pipe in its interior. At its lowermost part it is provided with an outlet, which can be closed by a slide valve, and at the top with a wide copper neck leading to the condensing apparatus and air-pump. It has also inlets for the admission of the liquor which is to be "boiled." The condensing apparatus is usually an iron cylinder about 6 feet in diameter, and 6 to 10 feet long, furnished with a supply of water which falls from its upper part into a perforated tray or trays, also with a wide pipe of about 40 feet in height, passing from its bottom into a tank of water below to take off the water used in condensing the vapour coming from the pan, and with another pipe from its top going to the air-pump. The air-pump has generally a diameter of about 20 inches, makes a 2-foot stroke, and is capable of removing so much of the air


COLD WATER PIPE
PIPE TO AIR PUMP
SYPHON PIPE

from the apparatus, that the remainder has only elastic force enough to support a column of mercury of 2 inches in height, instead of the 30 inches which it does when at full pressure. Now as a liquid boils (gives off bubbles of vapour) whenever the tension or elastic force of its vapour becomes greater than the pressure exerted on its surface, and as the tension of the vapour of all liquids is increased by a rise of temperature, it is obvious that they will actually boil at a much lower temperature in any vessel in which the atmospheric pressure has been wholly or partly removed, since the point at which the tensions of their vapours will exceed the remaining pressure on them, will be sooner reached.

In using the vacuum pan, the air-pump is set going, and when a partial vacuum has been formed, a cock is opened and enough of the decolorized sugar-liquor drawn in to cover the bottom worm. Steam is then turned on in that worm and in the jacket, and in a few minutes the liquor is seen through a glass provided for this purpose, to be in full boil; though the temperature, as shown by the thermometer, is only 130°–140° F. instead of 220°–230° F., at which it would boil in the open air. The boiling of this first portion is continued, until a small portion of the liquid withdrawn by the "proof-stick" shows, by its degree of viscidity, that the proportion of water has been so much reduced, that sugar is ready to crystallize out. This point is easily recognized by an experienced workman, but is very difficult to describe it with a useful amount of accuracy. Roughly speaking,

one may say that when a drop of the liquid taken between the thumb and finger will draw out to a thread more than three-quarters of an inch long, the proof-point for a good sugar solution has been reached. At this moment the liquor in the pan is *supersaturated* with sugar, and only needs to be disturbed in some appropriate way, in order to begin depositing some of that body in a solid form. This disturbance of the state of unstable equilibrium can be brought about with great rapidity and certainty by the introduction of some already crystallized sugar, but this course presents practical difficulties which do not attend the usual course of admitting small portions of the un-thickened solution of sugar with which the pan was originally charged.

In a few minutes after "giving the pan a drink," a portion of the liquor held extended between the thumb and finger will be seen to have small sparkling crystals of sugar floating in it; these will rapidly increase in number and size, until the whole mass of liquor is filled with them. When the contents of the pan cease to deposit more sugar, a fresh lot of liquor is admitted and its water evaporated. The sugar separated from this portion then deposits for the most part on the surface of the "grains" already formed. This drawing in of liquor and evaporation of its water is kept on until the pan is full, when the boiling is continued, till the mass has a consistency suitable to the treatment to which it is to be subsequently submitted. The size of the grains formed is mainly regulated by the

quantity of the grain made at first, since the fewer crystals there are to begin with, the more will they grow by the addition of the sugar afterwards deposited.

Up to this point the course of work is substantially the same, whether the object be to make "loaf-sugar," "crystals," or "pieces"; such differences as there are, being confined to the size of grain made in the pan and the degree of "stoutness" to which the boiled mass is brought before "letting down."

Supposing loaf-sugar is to be made, the contents of the pan are heated to a temperature of about 170°–180° F., either in the pan itself or in a separate "heater," and the hot "thin" magma of sugar crystals floating in the hot saturated solution of sugar is filled out into a number of conical iron moulds which are stood on the floor of the "fill house." The moulds and their contents are allowed to remain at rest for at least twelve hours, during the first part of which time the sugar is once or twice stirred in the face to ensure the regular formation and settlement of the crystals. On standing, the ready-formed crystals settle together, and, as the surrounding syrup cools, the sugar which it deposits serves to cement the whole mass firmly together. Since the solution of sugar originally evaporated was by no means pure, or even colourless, the evaporation of much of the water, and the separation of a considerable proportion of the sugar in the state of pure crystals, must obviously have left all the impurities crowded together in the comparatively small portion

which still remains liquid. This "green syrup" has to be removed from the crystals of sugar before the loaf can be dried for sale. To effect this, in the first place, the plug which has been used to stop the nose of the moulds is withdrawn, and a pricker driven a few inches into the solid sugar to make a channel through which the syrup can drain away; the mould is then stood on some sort of rack over a trough, and is allowed to stand till no more syrup runs. At this point, though the coloured syrup which filled the spaces between the crystals has been removed, still enough remains clinging to the surfaces to render the mass more or less yellow or even brown. To remove this last portion of coloured syrup, a perfectly colourless and saturated solution of pure sugar is poured on the face of each loaf and allowed to soak down through the crystals, to carry with it the impure syrup. This washing of the crystals is continued till the loaf is perfectly white all through. A couple of days is then allowed for complete draining, the loose sugar on the face is cut off, the loaf knocked out of the mould and the wet nose cut off. Nothing now remains but to dry the sugar, which is done by standing the loaves on racks in a large chamber ("stove"), heated by steam pipes to about 120° F., for a period of four to six days. The sugar so made is almost absolutely pure; as a rule there is not more than 0·1 to 0·3 per cent. of impurity (including moisture) in it, and whether the raw sugar used in its manufacture be "beet" or "cane," it is equally pure. It may be proper to add here, that when thus purified, there is no known

difference between the sugars proceeding from the one source or the other, and all assertions to the contrary are mere tricks of advertising.

If "crystals" are to be made, the grain is caused to grow to a large size in the pan, by making very little to begin with and then boiling hot and slow; if, when the pan is full, the grain is still not "strong" enough, a portion of the mass is let out and boiling resumed, with, of course, addition of fresh portions of liquor, and the letting out and refilling is repeated till the syrup left by the separation of pure sugar becomes so impure and sticky, that difficulty threatens to stand in the way of its perfect removal from the grain. The boiled mass, when let out of the pan, is kept stirred, while it is filled out into the sieves of the centrifugal machines in charges of two to four cwt. The centrifugal machine consists essentially of a vertical open-topped drum, mounted on a spindle and surrounded by a case. The walls of the drum are pierced by a great number of small holes, and the spindle is in connection with driving gear, by which it can be made to revolve, together with the attached drum, at a speed of from six to twelve hundred times in a minute.

When the pasty mass of crystals and syrup is first put in such a machine at rest, it lies on the bottom, but as soon as the sieve begins to revolve, the centrifugal force causes it to rise up and spread itself evenly over the perforated sides, and, as the speed increases, the syrup is forced out and driven against the walls of the casing, whence it runs through a gutter or pipe to a tank, where it is stored for future treatment. The

crystals, when thoroughly drained in this manner, sometimes receive a dash of water, while still revolving, to complete the separation of syrup, and are then removed after stopping the machine. This form of sugar has about the same purity as loaf sugar, though sometimes it contains about a half per cent. of moisture.

"Pieces" (soft pale yellow sugar), when made direct from raw sugar, only differ from "crystals" in having the grain much smaller and not "spun" so dry in the centrifugals, retaining therefore more of the syrup adhering to it, and being by so much the less pure. As a rule, pieces are made from the syrup drained from loaf sugar or "crystals," and the syrup which they contain being comparatively impure, the actual percentage of true sugar present rarely exceeds 90 per cent., and often falls as low as 80 per cent. The syrup from pieces is boiled again, if still sufficiently rich, and yields a crop of sugar still more impure, and the syrup from this second piece constitutes molasses or treacle.

Treacle, i. e. the uncrystallizable residue of sugar refining, when made from cane sugar, contains about 35 per cent. true sugar, and when made from beet, 50 per cent., which is prevented from crystallizing by the presence of the concentrated impurities of the original raw sugar, left by the successive removals of various crops of pure sugar crystals from the liquor. These impurities require so much water to hold them in solution, that the mass cannot be concentrated sufficiently to separate a useful amount of sugar without becoming so thick and sticky, that even if sugar did crystallize,

it would be impossible to separate it from the adhesive mother liquor. In the case of treacle from cane sugar, 20 to 35 per cent. of the foreign bodies present consist of altered sugar possessed of nearly as great a sweetening power as cane sugar itself, and which cannot therefore be regarded as worthless. "Beet" treacle, on the other hand, contains a very large proportion of saline constituents, which give it a bitter and nauseous flavour. The accompanying analyses may be taken to represent the ordinary composition of refiner's treacle from the two sources:

	Treacle from Colonial Sugar. Per cent.	From Beet Sugar. Per cent.
Sugar	35·0	49·0
Glucose (grape sugar)	32·0	3·0
Mineral constituents (ash)	5·5	12·5
Organic matter other than sugar (gum, &c.)	9·5	15·5
Water	18·0	20·0
	100·0	100·0

SUBSIDIARY PROCESSES.—REVIVIFICATION OF ANIMAL CHARCOAL.

Animal charcoal ("char") is made by heating bones to redness for some hours in closed vessels, and then breaking the black results into grain. The action of heat is to drive off substantially all the hydrogen, oxygen, and nitrogen, with some of the carbon of the gelatinous part of the bones, leaving the greater part of the carbon behind, intimately mingled with the phosphate and carbonate of lime. In good new char

the various constituents exist in about the following proportions:

Carbon (with trace of Nitrogen) ..	12·0	per cent.
Carbonate of Lime	7·5	"
Phosphate of Lime and Magnesia	79·0	"
Iron Oxide	0·15	"
Sand, Sulphate of Lime, Fluorine, and Traces	1·35	"
	100·00	

This mixture of porous substances possesses the power of absorbing some quantity of all the constituents of a solution of raw sugar (including sugar itself), and of holding them more or less firmly, especially those substances which, like the brown colouring matter, exhibit some tendency to pass into an insoluble modification. But the power of absorption is very limited, and therefore, after a certain quantity of raw sugar solution has been passed through a given portion of char, it is found that further quantities are no longer decolorized sufficiently for the refiner's purpose. It then becomes necessary to *revivify* the char, i. e. to restore its primitive purifying power. The first thing is to wash out and recover the sugar which has worked into the pores of the char, and this is done, as previously described, by passing hot water through the mass. But as many of the impurities which the char has absorbed are more soluble in water than in strong sugar solutions, they dissolve out in part along with the sugar, and render the weak liquor so obtained very much more impure than the original sugar which was

brought into work. Lime, potash, and soda salts, together with iron and albuminous and gummy bodies, are thus removed in part from the char, and accumulated in the liquor containing a comparatively small portion of sugar. It is the bad custom of some refiners to use this *sweet water* to melt the fresh raw sugar, which is, in effect, first taking dirt out, and then putting it back to be again removed. In all cases, this sweet water should be worked separately. After all the sugar has been got out, the washing being continued till very little more purification can be so effected, the char is then drained, removed from the cisterns, and passed to the *kilns*, which generally consist of a number of iron pipes, about five inches diameter, passing vertically through a brick chamber, kept at a red heat by a number of furnaces in its lower part. The pipes are open at the top where they come through the brickwork, and end below the fire-chamber in flat sheet-iron prolongations, which serve as coolers, to reduce the char below burning point before it is brought into contact with the air. The char thrown on the top of the kilns is raked down into the pipes where it is raised to redness, and the remaining organic bodies absorbed from the sugar destroyed. From time to time the bottoms of the sheet-iron coolers are opened and the char which filled them partially removed, while fresh portions of wet char are allowed to fall into the pipes to be, in turn, heated to redness, cooled, and drawn off for use. Of late years, revolving cylinders have come into use for reburning char, and are found to be very effective, but space will not admit of their description here. Another

process of revivification, patented by Dr. Eissfeldt, consists in repeatedly boiling the exhausted char with a weak solution of ammonia—but in the only case in which I have seen this method at work, it was not giving good results.

Removal of Foreign Bodies.—It was shown in the preliminary remarks on the chemistry of sugar, that various saline bodies form compounds with sugar, which, because they crystallize with difficulty and slowness, act as molasses formers, by preventing the solutions from being concentrated sufficiently to allow all the uncombined sugar to crystallize. Among these the salts of potassium, with various organic and inorganic acids, are those which occur most frequently and most largely. Quite recently a process for removing a large proportion of the potash present has been patented by the Messrs. Newlands, and has been already brought into extensive work in various refineries. This process is based on the fact that alum is but slightly soluble in cold water, and that it contains only one-tenth of its weight of potash. To the cold concentrated solution of a raw sugar or of a syrup containing not less than 1·5 per cent. of potash, enough strong solution of sulphate of alumina is added to convert all the potash present into sulphate, and to combine with the sulphate of potash so made. On standing, alum in large quantities crystallizes out and settles at the bottom of the tank in which the operation is performed. The clear liquor left, which is strongly acid, and which contains much alumina in solution, is drawn off and neutralized with lime or chalk, boiled,

filtered, and passed through char in the usual way. This process reduces the potash present to about one-half per cent. on the weight of the syrup, and, in addition, purifies the solution in another way, owing to the alumina which is precipitated on neutralization, carrying down with it some of the nitrogenous matter which is always found in low syrups. Many other processes have been proposed, from time to time, for the removal of various impurities from solutions of raw sugar, but owing to their not having found practical application on any great scale, they do not call for extended notice.

BUTTER AND CHEESE.

BY MORGAN EVANS (late Editor of the 'Milk Journal').

THE ordinary butter and cheese of commerce is derived from cow's milk by processes to be afterwards described. This milk is an aqueous solution of caseine, milk-sugar, a trace of albumen and small quantities of mineral matters, and holds also in suspension minute globules of fat. The quality of milk depends upon the amount of solids contained after evaporation, all else being water. The composition of average normal country milk, according to Professor Wanklyn, contains, in 100 parts, water 87·55 per cent., caseine 4·04 per cent., milk-sugar 4·63, fat 3·07, and ash 0·71 per cent. The total solids are thus 12·45 per cent., namely 3·07 per cent. of fat and 9·38 of "solids not fat." Exceptionally rich milk given by highly-fed cows in towns and those on very rich pastures in the country may contain 10 per cent. of solids not fat, and 4 per cent. of fat—making the total solids 14 per cent.—and 86 per cent. of water; and even a slightly higher percentage of solids is not unknown. The best flavoured milk, and at the same time of the richest quality, is attained when the cows feed on old and rich permanent pastures in summer, the flavour being particularly sweet, from the presence of certain small quantities of odoriferous plants in the herbage.

The precise influence of different kinds of food on the secretion of milk and on its quality has not been accurately determined. It is certain that abundant and rich food has a marked influence in increasing the quantity of milk, but, contrary to the generally received opinion, the quality of food does not appear to have a correspondingly great effect. The experiments of Professor Playfair, Dr. R. D. Thomson, and a few others, were continued for too limited a period, and, if narrowly scrutinized, they certainly do not establish the theories which some of them were evidently expected to elucidate. On the other hand, the late researches of Dr. Kuhn in Saxony, Professor Wolff in Wurtemburg, and Alexander Müller and Eisenstuck in Sweden, tend to prove that the composition of cow's milk remains very constant under all kinds of food, when liberally supplied. It has long been a theory, that foods rich in carbon increase the amount of butter fat in milk, and that foods rich in nitrogen will in the same ratio augment the caseine, in the one case yielding more butter, and in the other more cheese. But the investigations of Kuhn and others rather teach us, that the cow elaborates milk of similar quality from both kinds of food, albuminoids producing no more cheese than fatty substances, and the latter giving no more butter than albuminoids. Dr. Voelcker, however, has recorded, that at Cirencester in 1862 considerable variation took place in the composition of milk from the College cows, the milk in one day falling from 12½ of solids to 9⅓. But this is admitted to be evidently due to an insufficient supply of food, which is a

somewhat different matter to a similar change taking place, when a full supply of nutritious food of any kind whatever is given. No doubt, however, remains, that increased quantities of good food, whether rich in nitrogenous or non-nitrogenous substances, increase the quantities of milk to be derived from cows. Although the quality is not greatly influenced by a change of food so long as this is good and abundant, a great difference is observed between the composition of the milk of cows of different breeds. It is probable that the quality of milk differs more from peculiarity of individual constitution of the cow than from its food, and that a cow, for instance, that naturally gives a poor milk (say 11·75 of solids) cannot by the most judicious feeding be made to produce milk of the highest quality, or 14 per cent. Its character also depends upon the distance of time, after or before calving, at which the cow yields her milk. The first milk given after calving, called "colustrum," is very different in character to that given afterwards, and is suited only to the stomach of the newly-born calf, and not for human consumption. As the flow of milk also diminishes towards the time of the next parturition, it becomes richer. This appears to be proved by the larger amount of cheese per gallon of milk made in cheese factories in the autumn months, when the majority of the cows in the herd are approaching their time of calving. It may contain either 3 or 4·5 per cent. of fat, or a difference of 1½ per cent. of fat in the whole milk; so that, where a poor milk would yield 100 lb. of butter, the same quantity of the richer

article would produce 150 lb. The amount of caseine in milk never varies to such an extent as its fat. The importance to butter-making of obtaining cows, and of feeding them so as to produce milk rich in fat, is readily seen, provided also that the quantity which they yield be the same; but it is generally understood, that the heaviest milkers are not those that give the richest milk. The fair test of the merits of a cow for the dairy is the amount of butter or cheese which may be made from her during the whole year.

The specific gravity of average pure milk is 1·039, water being taken at 1·000. A gallon weighs nearly 10 lb. 5 oz., pure water weighing 10 lb. But as cream is lighter than skim milk, a milk very rich in cream has a lower specific gravity than that of common average character. A low specific gravity therefore, within certain limits, may be the result either of the addition of a small amount of water or the presence of a large amount of cream. The instrument used for testing the purity of milk by its specific gravity is thus an uncertain guide. With the addition, however, of a graduated tube, the cream meter, into which milk is poured and allowed to rest until all the cream is thrown up and the percentage read off, the true cause of variation may be found. The average amount of cream by measurement is 10 per cent. It may yield less, or it may yield more, and still the milk be genuine, for cream varies very much in richness, and may contain either 50 or 70 per cent. of water to fat. These instruments, however, are useful in dairies, as giving an approximate knowledge of the quality of

milk; but the only complete and reliable test is the total amount of solids in milk after the evaporation of its water.

Cows are fed either in the fields, in sheds, or in both. On pasture their food is the natural or artificial grasses which they forage for themselves. In sheds, they are fed on grass or hay, with the addition of chaff, roots, cabbage, tares, or rye, and small quantities of oil-cake, ground corn, meal, bran, peas or beans, given separately or mixed with other food. In towns and suburban dairies, brewer's grains are largely given at intervals during the day. A well-kept cow in full profit will yield from 2 to 4 gallons of milk daily, and a good average in a well-managed farm is from 500 to 600 gallons per cow annually.* In some town dairies, where only those continuing in full flow of milk are kept, and where any sensible diminution of the maximum yield leads to the immediate disposal of the cow, as much as 1000 gallons per annum is sometimes attained over each stall, or for each representative unit in the number of cows kept.

Milking is performed twice daily, once every twelve hours, early in the morning and again at the corresponding hour in the afternoon or evening. It is important that the cows be milked clean, as the last milk drawn, called "strippings," is excessively rich in cream, being the upper stratum of milk in the udder at the commencement of milking, and consequently rich in fat and containing about 18 per cent. of solid matter. Milking machines of various kinds have been

* Morton's 'Dairy Husbandry.'

introduced into this country and in America, and are intended to supersede the use of the hand in expressing the milk from the teats. They are however, for various reasons, objectionable in practice, and cannot be recommended for general use to the dairyman. The time usually occupied in milking a herd of cows is about one hour, one man or woman being employed to every nine or ten cows.

Butter.

Butter is made either from cream or from the whole milk. A slight percentage more butter (about 5 or 6 lb. per cwt.) can be made by churning the whole milk, but the process is necessarily more laborious than when cream alone is used, and converts all the milk, after the butter is abstracted, into buttermilk, at the loss of obtaining skim milk for domestic use, or for making skim-milk cheese. The common method is to make butter from the cream alone. For this object the milk is set in shallow pans from 3 to 4 inches deep, and skimmed twice during the next twenty-four hours, or it is entirely denuded of cream once only at the end of twenty-four hours. The surface of the milk is either skimmed, or the milk is drawn off by means of a plug, tap, or syphon. Shallow pans not more than 3 inches deep are to be preferred for setting cream, as the butter globules rise more perfectly and with less difficulty through a short than a long distance. The temperature of the milk room should be about 60° F. If above 65°, the milk

rapidly decays, and if as low as 55°, the milk, having an increased density, will not throw up all its cream. The cream, when taken away, is placed in a crock, and as it becomes added to by fresh quantities, it is gently worked with a wooden stirrer. Churning takes place either once, twice, or thrice a week, or even daily, according to the season of the year or the number of cows kept. It is usual to allow the cream to become slightly acid in the crock before it is churned. Considerable difference of opinion is, however, manifested on this point. Those who let the cream sour slightly, believe that the butter made from it is firmer, and keeps better than that made from fresh cream; while, on the other hand, it is contended that the fresher the cream when used, the finer is the flavour of the butter. The temperature of the cream when put in the churn should be about 62°.

Churns are made of various forms, and are worked either by hand, horse-power, water, or steam. The commonest form in England is the barrel-churn, resting horizontally on friction wheels and bearings at either end, and made to revolve on its axis by a crank-handle, for the purpose of agitating the cream by the action of the wooden beaters attached to the inner circumference. In America, the vertical churn, with a dasher worked up and down through the cream, is the usual form. There are several other kinds in use in this country and abroad, amongst which may be mentioned those known as box-churns, wherein the vessel holding the cream is stationary, and its contents

are agitated by a series of beaters revolving around a horizontal axis, the object of all being the same, to produce a mechanical agitation of the cream for the formation of the butter.

The fat globules of milk and cream are enveloped in thin shells of caseine. The manufacture of butter depends on agitating the milk or cream, so as to burst these little shells and let the butter fat free to coalesce in the churn in the form of large lumps of butter. Churning usually occupies from 30 to 45 minutes. It is not deemed advisable to hurry on the process in less time than half-an-hour, as the operation is not so perfect; and where vertical churns are used, the dash strokes should be no quicker than about fifty per minute. When the butter has gathered in the churn, it is taken out and washed in cold spring water for the purpose of ridding it of its buttermilk and the small particles of caseine which, if allowed to remain, would soon decay and turn the butter rancid. After it has been washed or rinsed, the butter is kneaded or beaten into a firm mass for the expulsion of its water, salted according to taste, and then packed for the market, according to the fashion of the district or the character of the article. Fresh butter should contain little more than 1 per cent. of salt. Best salt butter contains from 3 to 6 lb. per cwt., according to make, and the market which it is intended to suit.

Colouring matter is sometimes added when a yellow or golden hue is desirable. This is done by the addition of annatto to the cream, or by grated carrots

being put to steep in it overnight, and which are strained out next morning, when it is poured into the churn.

It takes from 22 to 24 lb. of milk, according to the quality, to make 1 lb. of butter. A cow that gives from 8 to 12 lb. of butter a week during the butter season, may be considered a good one for dairy purposes. Mr. J. C. Morton says, that well-selected cows will produce from 2 cwt. to $2\frac{1}{4}$ cwt. of butter each per year on an average. The majority of ordinary dairies, however, throughout the country can scarcely be averaged higher than $1\frac{1}{2}$ cwt. per cow per annum.

Butter, chemically considered, is a compound of various fats, such as olein, palmatin, stearin, and small quantities of peculiar oils, butyrin, caproin, and caprolin. It is to certain changes taking place in these latter, from decay, that the rancid flavour which butter sometimes has is principally due, and also to the action of traces of sugar of milk on the small amount of cheesy matter occasionally left in it. Salt is the best preservative of butter. When butyric and other volatile acids are formed, they give a disagreeable flavour; but they may in great measure be removed by washing, as they are soluble in water. Best fresh butter contains fat (82·7 per cent.), salt (1·1), water and a trace of organic matter (16·2 per cent.). Low-priced butters are generally found to be adulterated with large quantities of salt and water. An analysis of foreign butter, called "bosch," was found to contain 7·5 per cent. of salt and 29·7 per cent. of water

(Wanklyn); and even greater sophistication is not unknown to our food analysts.

The best fresh butter brought into the London market is what is called Aylesbury, but under this term is not only included that manufactured in the vale of that name, but also all the fresh butter similarly packed, and coming from the counties of Oxford, Bucks, Cambridge, and adjoining districts. It is sold in "flats," rectangular wicker baskets, containing from twenty to thirty lumps of butter of 2 lb. each. The best salt butter sold in London, especially in the early part of the year, is that made in Dorset, packed in casks or tubs, containing 56 or 112 lb. each. Irish butter is packed in firkins, and is of good quality, the best being frequently sold in London for Dorset. There is an extensive trade in Cork butter, and upwards of 400,000 firkins are annually branded in the Cork market. The character of Welsh butter is excellent, but it is principally consumed in the Welsh mining districts, as also in Birmingham and other manufacturing towns in the midland counties. Large quantities of good butter are made in Yorkshire, in the North of England, and in Scotland, which chiefly go to supply provincial towns in the localities in which such butter is made, or at the nearest market for the commodity.

It is impossible to estimate either the amount of labour expended in the dairy industries of Great Britain and Ireland, or the value of its produce in milk, butter, and cheese. It may, however, be stated that the "Agricultural Returns" for 1875 give 2,253,241 as the number of "cows and heifers in calf or in milk"

in Great Britain. It is also impossible to say what number of these were in calf at the time the returns were made throughout the country, as many of the animals would be available for the dairy but for a short time during the year. And any calculation as to how many are devoted to the supply of milk for towns, or for butter or cheese, must be under the circumstances extremely unsatisfactory. But that able authority on dairy statistics, Mr. J. C. Morton, in the 'Agricultural Gazette' says, speaking of the returns of 1873, which were 3,764,015 for the United Kingdom, that, deducting the counties of Chester, Gloucester, Somerset, Wilts, Berks, Derby, Salop, Stafford, and Leicester, as wholly cheese-making counties, the 1,595,296 cows and in calf heifers in England in 1873 would be reduced by 506,664. He adds, "How many of the remaining cows are set for the produce and the sale of milk, and how many hardly come to the pail at all during the year, we do not know, but this 1,000,000 which are left can scarcely be supposed to produce more than 50,000 tons of butter annually." The data, however, for such calculations are so vague, that it is useless to attempt to apply them to estimate the production of butter or cheese in Scotland from its 396,863 cows and heifers, in Ireland from its 1,526,500, and in Wales from its 261,082 dairy cattle.

The consumption of butter and cheese in the United Kingdom very far exceeds the home production, and the principal supply upon which we depend is obtained from abroad. It is believed by some, that two-thirds of our butter and fully one-half of our cheese is

derived from foreign sources; but there is no means of obtaining any reliable statistics bearing on the point, so that estimates of the kind must be taken for what they are worth.

In 1853 the duty of 10*s.* per cwt. on foreign imported butter was reduced to 5*s.*, and in 1859 it was entirely repealed. The amount of imported butter in 1852 was 287,266 cwt. only. By the year 1862, three years after the total abolition of the duty, it rose to 1,037,371 cwt. In 1869, 1,259,089 cwt. were imported, and in 1873 it reached 1,277,729 cwt. The latest complete returns of imports are those for 1874. The following table gives the names of the countries that supplied us in the latter year, and the amount and estimated value of the butter derived from them:

1874.	Quantities.	Value.
	cwts.	£
Sweden	23,292	138,070
Denmark	226,053	1,363,433
Germany	135,027	767,191
Holland	351,605	1,877,755
Belgium	76,723	465,517
France	713,251	3,944,233
United States of America	36,307	188,769
British North America	50,282	269,362
Other countries	7,268	35,695
Total	1,619,808	9,050,025

Small quantities of butter are exported from this country to our colonies and other places where there is a demand for special kinds to suit special customers.

Compared with our imports the amount is very small. In 1875 our exports were 39,281 cwt., of the estimated value of 240,204*l*. A large relative proportion of our exports—Irish butter—is shipped direct from Ireland.

CHEESE.

Cheese is made by coagulating the caseine of milk by artificial means, thereby converting it into curd, which is then treated in various ways and pressed into a compact substance of the desired shape. When cheese is made from whole milk, the butter-fat is also retained and held in combination in the curd. Curd may be formed either by the addition of an acid to the milk, by the juice of certain plants, or, as is the universal practice in this country, by the use of rennet, which is made from the stomach of a young calf. Its peculiar action in coagulating the caseine of milk is due to the presence in this stomach of minute cells contained in the gastric juice, and the process is one of fermentation, rapidly effected by a fungus called *micrococcus*, which has an extraordinary power of reproduction and development. In the preparation of rennet for dairy use, the calf's stomach, called "vell," is salted and then packed away in water in a jar or pot. A portion of the surrounding liquor having absorbed the active principle in the coats of the stomach, is mixed with milk, and curd is formed, and the first stage in cheese-making is thus entered upon.

Cheese may be either made from skim milk, from the whole milk, or from milk to which an extra

quantity of cream is added to increase its richness. Of whole-milk cheeses, the most popular and best known is that made on the Cheddar principle. Cheddar cheese is now largely made in England and in America on the most approved scientific method, and appears destined to supersede most other local systems of manufacture, although it was first made only in the small locality of Cheddar in Somersetshire.

The mean composition of six Cheddar cheeses analyzed by Voelcker was: water 34·6 per cent., butter 30·0, caseine 27·4, milk-sugar, lactic acid, and extractive matters 3·2, and mineral matters (containing common salt) 3·8 per cent.

The ordinary method of making Cheddar cheese in private dairies may be briefly described as follows. The fresh drawn morning's milk is mixed with that of the previous evening in a large tub, and the temperature raised to 80° F., by heating a portion of the milk and mixing it with the remainder. Rennet and a little colouring matter, annatto, are then added, and the whole is left to stand for one hour, during which coagulation takes place and curd is formed. The curd is now broken up with sharp knives or wire breakers into pieces about half an inch square, and the whey drawn off. A portion of the latter is heated and poured over the curd, to scald it at a temperature of 100°. This whey is again separated from the curd, which is put in a vat, and placed for a short time under a cheese-press for the purpose of expelling all the whey. The curd is now further broken up by hand or by a curd-mill, and salted at the rate of about 2 lb. in the

hundredweight. It is then placed in a mould and again put under the cheese-press. The cheese is bandaged with cloths and taken out of the mould, and turned daily for five or seven days. It is then neatly bandaged and removed to the shelf of the cheese-room, which should be well ventilated and maintained at a temperature of 75° by the use of stoves or heated pipes during cold weather. Whilst curing here, the cheese is daily turned, wiped, greased, and polished with a cloth or the hand, and in three or four months it is ready for the market.

In large dairies and cheese factories, where it is made on scientific principles and with scientific accuracy, a number of ingenious appliances are used, and the process is expeditive and made more perfect. The evening's milk, for instance, is placed in jacketed vessels, and will keep cool by being surrounded with a stream of cold water, which in passing away sets in motion an agitator, so as to prevent the cream from rising to the surface during the night. Jacketed vessels are also used to heat the milk, to scald and cook the curds by steam; cutters of most ingenious construction subdivide the curd horizontally and vertically; the whey is carried off and strained by inserting in it a cylindrical vessel of perforated tin, in which is inserted a syphon specially made for the purpose. The temperature is always regulated to the markings on a thermometer, and not, as in the old system, to the sense of feeling by dipping the hand in the whey or milk.

Gloucester cheese is either single or double, and

may be made from whole milk, or from mixing with the fresh morning milk that of the previous evening, after it has been skimmed. The latter kind is called "half coward." The method of making Gloucester cheese differs from that practised for Cheddar, inasmuch as the curds are not scalded during the process. The single cheese is flat and about 4 inches thick, weighing about 16 lb., but this kind is rapidly going out of fashion. It was principally bought by licensed victuallers for toasting "Welsh rabbit," but it is now generally replaced by English or American made on the Cheddar principle. The Derbyshire cheese is also a half-skimmed cheese. The cheeses of Cheshire, Somerset, and Wilts are principally of whole milk, made in ways slightly varying from the Gloucester, and the same may be said of the Dunlop cheese of Scotland. The Cheddar system now, however, seems to be the ideal of cheese-making in all these counties, and Scotch Cheddars have taken the place of "Dunlops" in the English markets.

Stilton cheese is principally made in Leicestershire; it is uncoloured and extremely rich in quality, as it is manufactured out of the morning's milk, with the addition of the cream of the previous evening's milking. The curd when separated from the whey is not broken as in making other kinds, but is drained and dried in a sieve. It is then placed in a wooden hoop on a dry board, frequently turned and wrapped in bandages, which are tightened at each manipulation or as occasion requires.

In districts where butter-making is the chief object

in the dairy, cheese is made from the skim milk only. It is necessarily a poor cheese, and fetches but a low price in the market. It is principally consumed by the labouring classes in the neighbourhood in which it is made, and is the staple kind retailed by the village grocer in such places.

From $9\frac{1}{2}$ lb. to 10 lb. of milk on an average go to make 1 lb. of whole-milk cheese. In other words, it may be said pretty accurately that with skilful management 1 lb. of cheese can be made from 1 gallon of milk. The average production per cow may be generally calculated as from $3\frac{1}{2}$ cwt. to $4\frac{1}{2}$ cwt. of cheese per annum.

Whilst the flavour of butter is greatly affected by the kind of food partaken of by the cows, no such influence, at least to any great extent, operates in regard to the character of cheese. Butter, for instance, made from cows eating turnips, has a strong "turnipy" taste, and the finest quality in flavour and aroma is only produced from grass or hay from the sweetest pastures. Although the richest cheese can only be made from cows and food producing the largest amount of butter fat—which, as we have seen, is the most variable constituent of milk—good, saleable, and even high-priced cheese, as Dr. Voelcker says, "can be made in any locality, whatever the character of the pasture may be, where an industrious and skilful hand, and an observant and intelligent head preside over the operation."

The most important feature in the history of cheese-making is the recent development of the factory system in Europe and America. Cheese factories may be

either owned by private individuals, and the milk bought from neighbouring farms at a fixed price, or, as is more usually the case, a number of farmers combine to erect a factory worked at a joint expense, and the profits divided *pro ratâ*, according to the quantity of milk that each supplies to the premises in the course of the year. The first country in which associate dairies were formed was, I believe, in Switzerland, more than thirty years ago. It is, however, generally spoken of here as the American system, for there it first became popular, and from thence it was introduced into England. The first cheese factory in America was established in 1851, by Mr. Jesse Williams, a farmer in Oneida County, New York, and a native, it is said, of Monmouth, in England. In 1854 four additional factories were established in New York state, and in 1861 twenty-one were in operation. From that time to the present, the numbers have increased to a surprising extent, and beyond the expectations of the most sanguine admirers of the system, for there are now about one thousand cheese and butter factories of all kinds in the state of New York alone, about one hundred in Ohio, and a considerable number scattered throughout the states of Illinois, Vermont, Massachusetts, Wisconsin, Michigan, Pennsylvania, and also in our own colony of Canada, and even in Nova Scotia.

The origin of the co-operative factory system of cheese-making in England dates from 1869, when a number of landed proprietors and farmers in Derbyshire banded together to establish a cheese factory in the town of Derby. A guarantee fund was subscribed and a suitable building secured. The chief subscribers

were Lord Vernon, the Hon. E. K. Coke, and Mr. J. G. Crompton, and they were ably supported by Mr. Alderman Roe, Mr. Nuttal, Mr. Gilbert Murray, and several others. Another factory was erected at Longford, near Derby, on the estate of the Hon. Mr. Coke, and built solely at his expense. The success that has followed the enterprise has been highly gratifying to the promoters, for at the commencement of the third season (1872) the milk suppliers were so satisfied with the undertaking, that they released the guarantors from any further risk, and assumed the entire responsibility and management of both factories themselves, which they have continued to work ever since on purely co-operative principles and with highly favourable results. The system undoubtedly offers considerable advantages to dairymen. By concentration of labour, the greatest economy in manufacture is attained, and by scientific management the greatest accuracy in the production of cheese of the most uniform and best quality is secured. The 'Report of the Derbyshire Associated Dairies for 1872' shows that there was a saving of nearly 400*l.* in that year in the cost of labour alone, compared with what would be imperatively required, had the cheese been made at home separately on the contributory farms. It also states that "not a single cracked or heaved cheese was made at either factory during the season, and that the cheese realized 10*s.* per cwt. (120 lb.) more than the average quotation for the Derby fairs." Again, the average gross receipts per cow over the whole dairies was at Longford 16*l.* 8*s.* 1*d.*, and at Derby factory 16*l.* 13*s.* 9½*d.*, which *must be* considered a most excellent return, and suf-

ficient to demonstrate the practical value of the system. Although at first the American system met with considerable opposition from landowners and farmers, its detractors are now well nigh silenced, and cheese factories multiply. There are at the present time nine in England in full working order, while several others are in course of erection, and many are in contemplation in various parts of the country. The following are the factories already in existence, and also give the approximate quantity of cheese produced in each, dependent on fluctuations, as the season is favourable or otherwise for the supply of milk:

Longford, Derbyshire	90 to 100 tons
Derby "	30 " 40 "
Windley "	40 " 50 "
Mickleover "	35 " 45 "
Lichfield, Staffordshire	45 " 55 "
Holms "	25 " 35 "
Hope Dale "	25 " 35 "
Tattenhall, Cheshire	20 " 30 "
Highbridge, Somersetshire ..	40 " 50 "

The average aggregate is thus about 400 tons per annum. It may be added, that the factory system has already extended on the Continent to Russia, Holland, Denmark, Sweden, and other countries.

The consumption of cheese in the United Kingdom far exceeds the home production, but by how much it is difficult to say. As has before been remarked, some authorities estimate that fully one-half the cheese sold in England is derived from abroad, but this is at best but a guess, and does not admit of verification. Our principal foreign supply comes from America, where

the best factory cheese rivals our own in quality. Our exports are practically *nil*, and so small as not to find place in the official returns. Small quantities of Wiltshire loaf—rich cheeses weighing from 14 to 16 lb. each—and a few other kinds are, however, being continually sent to our colonies, to the Continent, and elsewhere. The duty on all foreign cheese previous to 1842 was 10*s*. 6*d*. per cwt. In that year the duty on the imports from British possessions was reduced to 2*s*. 3*d*. per cwt. A further reduction took place in 1843, when foreign butter paid only 5*s*. 6*d*. duty, and that from our dependencies 1*s*. 6*d*. The former was again reduced to 2*s*. 6*d*. in 1853, and the duty on all imports of cheese was entirely abolished in 1859. In 1866 the entire amount imported was 872,342 cwt. In 1869 it was 1,259,089, and in 1873 1,277,729 cwt. The following is a statement of the quantity and value of cheese imported in 1874, and the countries from whence it came:

1874.	Quantities.	Value.
	cwts.	£
Sweden	3,132	11,627
Germany	4,383	13,104
Holland	398,888	1,164,921
Belgium	1,625	5,442
France	5,487	20,741
United States of America	849,933	2,589,776
British North America	221,043	675,995
Other countries	774	2,321
Total	1,485,265	4,483,927

BREWING.

By T. A. Pooley, B.Sc., F.C.S.

The term "to brew," in its usual acceptation, means to manufacture an alcoholic and saccharine beverage from malt and hops, to which the name *beer* has been given; and although many other fluids are prepared by a system of brewing, yet it is to the manufacture of beer that this article will be devoted; and under this head will be included the different varieties, such as ale, porter, stout, &c., which are known in this country, and the production of which forms so important an industry.

From the earliest times and in every clime man has had resort to some stimulating and exhilarating beverages prepared by fermenting the juices or extract of fruit, grain, or plants. In Russia, a fermented drink called "quass" is prepared from rye; in South America the juice of the American aloe is fermented and made into a beverage called "pulque," and another called "guarapo" is produced from the juice of the sugar cane. In Tartary the famous "koumis" is a fermented liquor made from mare's milk; the Chinese prepare a similar fluid from rice; in Peru a fermented beverage called "chica" is obtained from maize; the Arabians and Abyssinians manufacture

one from millet and barley; in New Zealand the Maoris extract a beverage from a plant peculiar to their country; in the southern countries of Europe the juice of the grape is manufactured to an enormous extent into wine, of which there are endless varieties; while in the northern portions of Europe, the favourite beverage is prepared from the extract of barley flavoured by the addition of hops. All these, although diverse in flavour, resemble each other chemically, being *de facto* saccharine fluids partly fermented. It is remarkable to observe how all races of men have had recourse from the earliest times to these fermented beverages; and in the present day, when we hear so much of the ill effects produced by their use, it may seem perhaps strange to assert that they are essential to man, though their universality would appear to show that it is so, and it is only their "abuse" which has led to misery and immorality.

In the present article it is proposed to confine the subject to the brewing of the different varieties of beer known in this and other European countries, and with this view it will be divided under four heads, viz. history, materials, process of manufacture, and statistics.

1. History.

Although brewing is one of the oldest arts, yet the productions of earlier times differed very materially from those of the present day. It is said that Osiris,

as early as 1960 B.C., taught the use of extracting a juice from barley and fermenting it, while the Greeks learnt how to brew a fermented beverage from the Egyptians, who, as early as 300 B.C., had established a number of manufactories at Pelusium, on the Nile. Xenophon, 400 B.C., refers to a fermented drink from barley, and it is also alluded to by Aristotle, Strabo, and others, under the name of zythos. Pliny mentions a kind of beer called "cerevisia," and Eumenes, in A.D. 296, says, "Britain produces such abundance of corn that it was sufficient to supply not only bread, but a liquor comparable with wine;" and Tacitus has also referred to beer being at his time the common drink of the Germans.

In the seventh century beer had become so general a beverage in Britain, that Ina, King of Wessex, levied a tax to be paid in ale.

Early in the fifteenth century the trade of brewing had so far advanced in London that a Brewers' Company was formed, and we read that "they tried to curry favour with the then Lord Mayor by making him a present of an ox, which cost 21*s.* 2*d.*, and a boar priced at 30*s.* 1*d.*, so that he did no harm to the brewers, and advised them to make good ale that he might not have any complaint against them."

Chaucer speaks of ale manufactured in Southwark in his 'Canterbury Tales':

> "I am dronke, I know it by my soun:
> And therfore if that I misspeke or say,
> Wite it the ale of Southwerk, I you pray!"

The price of ale at this time appears, from the records of the Northumberland House book, to have been about 2*d.* per gallon; beer, ¾*d.* per gallon; hops, 13*s.* 4*d.* per cwt.; malt, 4*d.* per quarter.

In the sixteenth century the trade had so far advanced, that the London brewers exported very large quantities to the Low Countries, but up to this time the English ale was very poor, only flavoured with broom, bay berries, or ivy berries. Hops had been used in the beer manufactured in Germany, and large quantities of this came into England; but in 1524 we commenced in this country to cultivate the hop plant, and from this time a great change was made in the quality of beer manufactured.

> "Turkey, carpe, hoppes, piccarel, and beer
> Came into England all in one year."

Stow says that in 1585 there were twenty-six breweries in the City and Westminster, and they brewed as much as 648,960 barrels of beer in the year.

In 1610 the first brewery was established at Burton-on-Trent, now so famous for its colossal trade, and by the end of the seventeenth century beer had become the national drink, and was held in great estimation, as may be seen from the writing of Dr. Westmacott: "Old English ale is a most wholesome connatural drink. He that in his young days accustometh himself to drink his ale mixed or dashed with a little beer, shall never when he is old have occasion to repent, for beerish drink keeps the stomach clear, excites the

appetite, and carries off all ill humours; whereas fat, new, ropy, sweet ale (too often none of the clearest), dulls the appetite, creates clam in the viscera, and lodges too long. For myself, ye may conclude that I am a toper at old beer, by my appearing such an advocate for it."

This quotation shows the change that was taking place in taste, and how the preference was being given at this time to the clear tonic-hopped beer, over the old sweet barley wine or ale.

In 1760, according to the Annual Register, there were fifty-two London breweries, producing 975,217 barrels, the largest of which were Calvert's, Whitbread's, Truman's, and Thrale's (now Barclay, Perkins, and Co.), all firms in existence at the present day.

In 1761 was published the first edition of Michael Combrune's 'Theory and Practice of Brewing,' the first work that attempted to treat of this industry on scientific principles; in the preface it is stated that "in England and Wales 3,500,000 quarters of malt are brewed yearly, for which purpose upwards of 150,000 cwt. of hops are used."

From 1761 the manufacture of beer made giant strides, until it is now one of the most important industries in the kingdom; later on, under the head of statistics, I propose to give a *résumé* of the present position of the trade.

2. Materials.

The three principal materials which the brewer uses are water, malt, and hops. I shall give a short account of these substances, more especially malt, as that is the most important constituent in manufacturing beer.

1. *Water.*—Until the last few years very little importance was attached by brewers and distillers to this material, for it was not thought that the quality of the water affected the process to any extent; but as the brewers in certain districts, more especially Burton-on-Trent, became famous for the article that they produced, the attention of manufacturers was called to the composition of the water, and it was then found that in those places where beer was brewed, capable of withstanding the effects of long keeping and hot climates, the water contained certain mineral constituents in large proportions. From this it was assumed that these mineral constituents exerted a beneficial action, but at the present time considerable difference of opinion exists as to this question, many believing that the mineral constituents which are found so largely in Burton water are not so important, as that the water should be free from all impurities of an organic origin.

Water is never found in nature in a state of purity, but is always more or less contaminated with mineral and organic matter, either held in solution or suspended therein. No water should be used for brewing purposes unless it is clear and bright; if it is at all turbid when drawn from the well, it ought to be allowed to stand, in order that the suspended matter may settle,

or else it should be passed through a filtering medium. The principal inorganic or mineral matters found in water are:

Calcic carbonate (chalk)	Magnesic sulphate (Epsom salts)
Calcic sulphate (gypsum)	Potassic sulphate
Calcic nitrate	Potassic nitrate (saltpetre)
Calcic chloride	Sodic chloride (common salt)
Magnesic carbonate	

The organic matters usually found in well and river water are such as are derived from drains, cesspools, decaying animal and vegetable matters, &c., and in addition certain gaseous bodies are generally found dissolved in water, such as carbonic acid, oxygen, &c.

The following are a few analyses of some well-known waters.

River Waters.

	River Thames.	River Trent.	River Dee.	River Don.
Calcic carbonate	10·80	0·32	0·85	2·23
Calcic sulphate	3·00	21·55	0·12	0·13
Calcic nitrate	0·17	..	..	..
Magnesic carbonate ..	1·25	5·66	0·36	1·07
Sodic chloride	1·80	17·63	0·72	1·26
Silica	0·27	0·72	0·14	0·52
Ferric oxide and alumina	Traces	Traces	Traces	Traces
Calcic phosphate	Traces	0·50	0·60	0·27
Organic matter	2·36	3·68	1·64	3·06
Grains per imperial gallon	19·65	50·06	4·43	8·54
Hardness	14°·	21·5°	1·5°	3°·

WELL WATERS.

	Burton.	Newark.	Well Park, Glasgow.	Granthams.	Stratford-on-Avon.
Sodic chloride ..	10·12	1·96	2·40	10·51	6·02
Sodic sulphate ..	..	1·89	8·70	..	..
Potassic sulphate ..	7·65	0·65		..	1·20
Calcic sulphate ..	18·96	16·49	7·20	10·66	35·89
Magnesic sulphate	9·95	7·40	1·50	..	49·02
Calcic carbonate ..	15·51	11·06	8·00	26·10	21·42
Magnesic carbonate	1·70	..		2·45	1·15
Ferric carbonate ..	0·60	..	..	..	..
Ferric oxide	..				
Alumina and phosphates	..	1·82	0·10	1·19	Traces
Silica	0·79	0·54	0·70	0·32	0·49
Organic matter ..	..	1·91	0·30	8·63	6·26
Alkaline nitrates ..	..	..	..		
	65·28	43·72	28·90	59·86	121·45

Calcic and Magnesic Carbonates occur in certain proportions in all well and river waters; the so-called "hardness" is due partially to these substances, but as they may be removed by boiling the water, the hardness is described as "temporary." These carbonates are advantageous in the process of mashing, for the carbonic acid is easily replaced by any other acid, and thus the lactic acid of the malt is to a certain extent neutralized.

Calcic Sulphate is found in most well and river waters, sometimes in very small, and occasionally in ex-

tremely large quantities in certain districts, as at Burton-on-Trent for instance, and it may be inferred that the quality of the beer brewed at Burton is in some way dependent upon this substance. Calcic sulphate exerts a very marked influence upon albuminous bodies. Malt contains besides starch and dextrine, a quantity of albuminous bodies which are very prone to decomposition; the calcic sulphate in the water rendering these to some extent insoluble, they are precipitated, and the too rapid fermentation of the wort is avoided. In addition to this action calcic sulphate appears to affect the flavour of the beer. Notwithstanding its manifest advantages in some respects, its presence in water is injurious to the beer to a certain extent, as it eliminates a portion of the most nourishing constituents of the malt.

Calcic Nitrate occurs occasionally in well and river waters, although usually in very small quantities; it is derived from the oxidation of decaying nitrogenous matters, and on this account any sample of water containing much of this salt should always be looked upon with suspicion, although in itself it is not only harmless but rather beneficial in its action in the same way as the calcic sulphate.

Magnesic Sulphate contributes to the so-called "hardness" of water, and it is not separated by boiling; its action is similar to that of the corresponding lime salt.

Sodic and Potassic Chlorides are generally present in all samples of water; they have no particular effect upon the operation of mashing, but as they are largely

derived from drainage matters, their presence usually indicates other impurities.

The Alkaline Phosphates and Carbonates are not often met with in any quantities.

The organic impurities of water are entirely of a different nature to those which have been referred to above. They are derived from decaying animal and vegetable matter, and their characteristic property is that of being destroyed by heat. Nearly all waters contain more or less organic matter, and some are distinctly discoloured brown by it. A very fair rough test for organic matters in water is to place a glassful on a sheet of white paper, and if the quantity be very small no colour will be observed, but if it be large the water will exhibit a decidedly brown tinge. The organic matter in water is always undergoing decomposition, and acts in the same manner as a ferment; it is therefore extremely prejudicial to malting and brewing operations, for it commences a fermentation before the proper time has arrived. There is little doubt that many of the anomalous results connected with brewing are due, to a very large extent, to the presence of organic matter in a state of decay in the water which is used. If there is reason to believe that the water is contaminated with organic impurities, an analysis should be made, and steps taken to purify the water before using it for brewing or distilling.

2. *Malt.*—Whilst the juice of the grape, of the sugar cane, of beetroot, and innumerable other vegetable

substances, contain in their normal state considerable quantities of saccharine matter, the farina or flour of ordinary grain requires to undergo a process of manufacture before it becomes sweet, and it is this process by which the seed acquires a sweetened taste, rendering it available for brewing and distilling purposes, that is designated "malting."

In this country the only grain which is used for conversion into malt is barley, and it is usually a trade of itself, although considering it is only one of the stages through which barley has to pass before it becomes beer or spirit, it would be preferable if undertaken by the brewer or distiller himself. On the Continent it is the usual practice for the brewer to manufacture his own malt, and it would be better were it more often the case in this country, for then he would be able to make it of regular and definite quality, while in a pecuniary point of view, there would frequently be a saving, as the carriage of grain to and from a distance would in many cases be dispensed with. A maltster has been known to purchase barley in Scotland, manufacture it into malt in the south of England, and then sell it to a brewer in Scotland; there may be and doubtless are reasons why malting has been and is carried on as a separate trade, but logically with the same reason, the process of mashing might be performed by one person, fermenting by another, and so on; they are only links in one chain of operations, and ought to be carried on by one manufacturer.

The essential constituent of barley is starch, which, as well as other matters contained in barley, is insoluble in water, and the object of malting is to convert these bodies into such a state, that they shall dissolve when treated with water at a certain temperature; these changes are brought about by the combined action of air and water, and a process called germination.

By germination the latent vitality of the embryo is brought into activity, for the seed contains within itself all the characteristics of the future plant, and also a supply of properly constituted food, sufficient to nourish the young plant until such organs are formed as are capable of absorbing and assimilating nourishment from the surrounding media. The essential conditions for germination are, that the seed should have a supply of air and moisture, and be kept within certain limits of temperature; for seeds when placed under the most favourable circumstances *in vacuo*, or in an atmosphere of pure nitrogen, hydrogen, or carbonic acid, never exhibit signs of germination. It is well known, that if seeds are buried very deep in the soil, they will not germinate at all, or at least not for a very considerable time, and this is due to the absence of a supply of oxygen; the effect of this gas being to combine with some of the carbon of the grain, thus forming carbonic acid, which is evolved. All ripe seeds contain organic compounds very rich in carbon, and substances which contain much carbon are never so soluble in water as those which contain little; the result of germination is the conversion of some insoluble constituents of the grain into soluble. The

following analyses by Dr. Thomson show the loss of carbon which takes place during the process of germination:

	Dry Barley.	100 Parts of dry Barley produce 84 Parts of Malt.	84 Parts calculated to 100.
Carbon	46·1	37·2	44·3
Hydrogen ..	6·6	5·9	7·0
Nitrogen ..	2·0	1·2	1·4
Oxygen ..	41·4	38·4	45·7
Ash	3·9	1·3	1·6
	100·0	84·0	100·0

It is also necessary that water should penetrate into the substance of the grain in order that the whole mass may become soft; at the same time certain constituents dissolved in the water are absorbed, and when so dissolved they react one upon the other, by which new compounds are formed.

Heat is absolutely necessary to germination. No seeds will germinate at the freezing point, and on the other hand, most seeds lose their power of germinating when exposed to a temperature of about 110° F.

Light is generally considered prejudicial to germination. Hunt made a series of experiments on actinism, that is, the effect produced by the differently coloured rays of light, and found that the blue rays were favourable, whilst the yellow rays were detrimental. Germination is said to be quickened by connecting the seed with the negative pole of a feeble galvanic apparatus, whilst it is retarded by being connected with the positive

pole. The process of germination is really an imitation of nature, and therefore the seed should be placed under conditions resembling as much as possible those it would meet with, if it were placed in the soil to grow. The identity of the process as brought about by art for the purposes of malting, with that for the reproduction of species by nature, has been to a great extent overlooked by writers. As regards the choice of barley for malting purposes, practical experience and results must be the main guide. The maltster's object is, to select such barleys as will "grow," that is germinate, and from which he may anticipate the richest yield of malt. Chemical tests are of importance, but he seeks a sample which possesses a bright, thin and wrinkled husk of a pale yellow colour, enveloping a plump, round, well-nurtured kernel, which, when bruised, appears chalky.

Malting is divided into four operations, viz. steeping, couching, flooring, and kiln-drying.

Steeping.—The object of this is to wash and cleanse the grain from earthy and other impurities, and to soften and completely saturate it with moisture. To effect this, the barley is placed in a cistern and covered with water, which is changed once or oftener during the operation. By excise regulations the maltster is not allowed to remove the barley from the steep cistern for forty hours. The water dissolves out some of the soluble constituents of the grain, and this loss amounts to about 1½ per cent., a considerable portion being composed of mineral matter, though some of the organic principles are also dissolved. If the steep water is

tested with a properly prepared solution of copper, it will be found to give indications of sugar and dextrine, and if with a solution of sub-acetate of lead, the presence of albuminous matter is also shown. Carbonic acid is also liberated, as may be seen by testing the bubbles of gas which escape. Abroad the following method of steeping is adopted: the grain is washed and rinsed with water, with which it is allowed to remain in contact for about two hours, during which time the husk becomes saturated, although the water does not penetrate to any extent to the interior of the grain; it is then drained and placed in a heap, and occasionally sprinkled with water, care being taken not to add more than can be absorbed. The grains are turned from time to time, and more water is added, until they refuse to imbibe it; and in this system no appreciable loss of valuable constituents takes place, while the moistening of the grain, which is really the object of steeping, is quite as well effected, as by the method which the excise authorities enforce our maltsters to adopt. It is of importance that the barley should be moistened equally throughout the whole mass, in order that the future operations may go on regularly, and that a uniform sample of malt may be produced. The barley swells considerably in the process of steeping, and this increase amounts to about half its weight and about a quarter its volume.

Couching.—After steeping, the barley commences to go through the changes necessary for its conversion into malt. The water is run off and the grain is drained, and placed in the "couch" where it is gauged

by the excise; the temperature now rises, until it is about eight to twelve degrees higher than that of the air, by which time the grain becomes dry to the touch. It is now necessary to regulate the temperature, and for this purpose it is removed from the couch and placed in layers varying in thickness, according to the state of the atmosphere; if the barley is now examined, a little white projection, the radicle or rootlet, is seen at one end of the grain, and affords a sign that it has commenced to germinate. It is necessary to the success of the operation that the germination should not take place too rapidly, and that too high a temperature should not be produced, and with this view the barley is removed to the floor.

Flooring.—The germinating barley is now placed in layers on the floor of the malt-house, and the temperature is regulated by increasing or decreasing the thickness of the layers. A series of changes commence in the composition of the grain, as the growth of the rootlets proceeds. Barley contains starch as its principal constituent, and this is partially converted into dextrine; at the same time the nitrogenous constituents are very considerably altered by germination, a portion of them being rendered soluble, and it is found that these possess a very peculiar quality, viz. that of converting starch into dextrine and ultimately into sugar. The name "diastase" has been given to the substance which possesses this property, but at present it has never been isolated, and consequently its chemical characters and composition have been ascertained no further than that it is capable of producing this remarkable change. It

is extremely doubtful, indeed, whether any such body exists, and it seems more probable that several nitrogenous compounds in a state of decay are the agents which bring about the transformation. The nitrogenous constituents of the barley undergo a change during the germination of the grain; and the early growth of the plant takes place by the aid of these bodies, the acrospire and rootlet, which are first developed, containing very large quantities of nitrogen; barley thus loses by malting some of its most nourishing constituents in the form of rootlets or "comings," and also in the acrospire which is not dissolved in the mash-tun. The essential changes which take place on the floor are confined principally to the nitrogenous constituents, for, although analysis shows that malt contains more dextrine and sugar than barley, yet this increase is not great, and a very considerable portion is produced during the subsequent operation of kiln-drying. It is the custom now with many maltsters to sprinkle the grain with water whilst on the floor, and in many cases this is found to be advantageous.

Kiln-drying is the next and final operation of malting. When the process of germination has proceeded sufficiently, the grain is removed to the kiln to be dried; at which stage the acrospire should be about one-half to two-thirds grown, when it becomes necessary to stop its further development. The thickness of the layer depends upon the variety of malt required to be produced, the heat being from 90° to 100° F. until the moisture is driven off; when the malt becomes dry, the temperature is raised to 140°, or even

170° F., according to the desired colour. Whilst kiln-drying is essential for driving off the moisture, it has further beneficial effects, for a portion of the hitherto unconverted starch is by the action of heat also transformed into dextrine, and, besides, it produces certain empyreumatic substances which give a characteristic flavour to the malt.

Before leaving this portion of the subject, attention should be drawn to a proposal by a Mr. N. Galland, for an entirely new system of malting; it does not appear to have been introduced into this country at present, but it seems likely to revolutionize the usual system of manufacture. Mr. Galland constructs his malt-house with a number of vaulted compartments, the floors of which are made of perforated sheet iron. The barley, previously washed and steeped by an improved arrangement, is spread on these floors, and fresh air, which has passed through cylinders containing coke saturated with water, is pumped through the grain; a temperature of 54° is maintained, and, if necessary, ice is added to the water and coke to reduce it; and in this way air completely saturated with moisture and at an uniform temperature is being continually forced through the grain, until the process of germination has proceeded sufficiently far. The advantages which Mr. Galland claims for his invention are, that the surface of the germinating floor is reduced four-fifths, while the manual labour is reduced one-half, and may be performed by ordinary labourers.

The germination goes on with an absolute regu-

larity during all seasons of the year, and none of the grains are mutilated during the process.

The following are Stein's analyses of barley and malt:

	Barley.	Malt.
Soluble albuminous compounds	1·258	1·985
Insoluble ditto	10·928	9·771
Cellular matter (husk, &c.) ..	19·854	18·817
Dextrine	6·500	8·232
Fatty matter	3·556	3·379
Inorganic matter	2·421	2·291
Extractive matter	0·896	4·654
Starch	54·282	50·871
Loss	·305	..
	100·000	100·000

As to judging the quality of malt, the practised eye is, perhaps, better than any chemical tests, although the latter ought not to be despised, for as regards some constituents, more especially lactic acid, it is only by chemical analysis that the quantity can be estimated. In 1808 Reynoldson wrote as follows, and no better description of good malt can be given:

"You will find a perfectly grown and enlarged acrospire, a crisp husk completely filled with kernel, which is sweet to the taste and friable, but yet not so soft as to crumble to dust under the slightest impression; a peculiarly pleasant smell, free from smoke, and not having that pungent warmth of taste contracted on the floors by the dry and heated process—these are indications of good malt from which a delicious extract may be expected. The man of science,

however, will look still farther, for he will appreciate the qualities of the article by the principles of chemistry and philosophy likewise in addition to the foregoing tests recommended."

3. *Hops.*—Hops are the female flowers of the *Humulus Lupulus*,* a plant which is grown to the greatest perfection and in the largest quantity in Kent and Sussex, but is also cultivated to some extent in the counties of Surrey, Hampshire, Worcester, and Suffolk. Foreign hops now find their way into the English market, but are generally considered to be inferior in quality to home-grown hops, and of these the Bavarian, Belgian, and American are best known.

It is not my object to describe fully the cultivation of the hop, and a few general remarks will be sufficient. The soil should be rich, deep, and dry, and if clayey or somewhat peaty, it is preferable. An abundant supply of either farmyard or artificial manure is absolutely necessary, as very few plants are so exhaustive to the soil as the hop-plant. The hop is an example of what botanists understand by diœcious plants, that is, such as have male and female specimens.

The flowers as used by the brewers are the female, the male being useless individually; but it is known by experience, that when the male plants are present to impregnate the female, the latter are far more numerous and better in quality. During its growth, the hop-plant is subject to a variety of dangers from the attacks of insects, and from the formation of mould on the leaves, which tend to reduce the produce, and

* Nat. Ord. *Urticeæ.*

also lower the quality of the flowers. But by far the most important operations in connection with hops are the drying and packing. About the beginning of September they ripen, and when ripe they should be picked immediately, or else they are liable to turn brown and lose all their flavour and aroma; they are taken direct from the ground to the kiln to be dried, though sufficient care is not generally taken to preserve them from moisture during the picking and passage. The oast-house, as it is called, where the drying takes place, resembles a malt-house, the kiln being usually circular, and the floor on which the fresh hops are laid being formed of hair-cloth or wire; below are several small furnaces in which coke, anthracite, or charcoal are burnt. The heated air ascends through the kiln floor and the hops, and then escapes through a cowl at the top of the oast-house. When dry, the hops are taken off the kiln, and laid out on a floor to cool; whilst there they are found to undergo a slight change, being first dry and crisp, but after a few hours becoming clammy, and, when packed, sticking together instead of crumbling up. They are now placed in large bags, and pressed down by a man jumping in the pocket as the hops are thrown in.

Such is the crude and old-fashioned method of preserving hops, and no hop farmer appears to have any idea of improving the system. Of temperature and thermometer he is perfectly ignorant, for he has always dried them thus, as his father did so before him, and the hop factor buys them; what more does he want? Yet he will allow that the quality of the

hops depends to a great extent upon the care taken in drying. If he finds that they have turned somewhat brown, he says that too much heat has been used, and thus he really makes use of his hops as a thermometer. The whole system is radically wrong; first of all the hops should not be picked if possible after rain, and from the time they are gathered to when they are placed on the kiln, they should be carefully preserved from moisture; while, during drying, the temperature should be kept very low, not higher than 160° F. at the commencement, and it never ought to reach 212° F. As a source of heat then it would be far better to use hot water, rather than heated air; a much more equal temperature would be obtained, and the hops would not suffer from too much heat, and consequently would be brighter and lighter in colour. Anyone who has passed near an oast-house at the time when hops are being dried, cannot have failed to observe the strong odour which prevails; it is precisely that delicate aroma, which is the great object of the brewer to give to the beer; and it at once suggests the idea, that the system is defective which allows the escape of so much of the valuable constituents of the hops. This aroma is produced by the volatilization of a peculiar ethereal oil which is found in them, and although this oil does not boil till a temperature higher than 212° is reached, yet, in common with other essential oils, it is found to escape at a far lower temperature when vapour of water is also driven off. Thus will be seen the reason for urging the importance of keeping the hops dry, before they are placed on the

kiln, and of using a degree of heat as low as possible to desiccate them. Under the present system, it is the practice of the hop dryer to burn some sulphur in the furnace, the sulphurous acid from which, in its passage through the hops, exerts its well-known bleaching action. The quantity of sulphur is very often by no means small, sometimes as much as 84 lb. to the ton of hops, and it is therefore not to be wondered at that the brewer is so often calling out about sulphured hops and their influence upon his fermentations.

Hops should be of light yellowish green colour, with no brown flowers amongst them, and, when rubbed, should leave on the hand a greenish resinous matter, with the peculiar odour of the hop. The great difference in the appearance of hops is dependent more upon the care taken in drying, than upon the growth; just as the quality of malt depends as much upon the care taken in malting, as upon the barley used. Lastly, in order that the hops may be preserved for a considerable time without loss of their essential constituents, they are pressed into bags, or pockets, as they are called, in the manner described above By experience it is known that the tighter they are packed, the better will they keep, and therefore as much pressure is used as possible under the primitive method now adopted. It will be seen shortly, that it is essential to the proper preservation of the aroma, that hops should be excluded from the air, and therefore it would seem an improvement upon the present system, that they should be packed either in some air-tight material, or

else that they should be compressed to a very much smaller space, either by steam power or by an hydraulic press. A brewer well knows the difference between the aroma of a pocket opened in October and a pocket of the same sample of hops opened in the following summer, and he is also aware that at the latter time, the centre of the pocket is better than the exterior; and such evidence is sufficient to prove that some loss of the virtue of the hop takes place, and at once shows the necessity of precautions being taken to reduce this loss to a minimum.

The use of hop in brewing is twofold; first, imparting to the beer a pleasant taste and an agreeable odour, and secondly, exerting a preservative action. Of the many substitutes that have been proposed, none combine these two qualities. Amongst other matters, hops contain as important constituents, an essential oil, a bitter principle, and tannic acid, but these bodies are not in equal proportions in the different parts of the flower. The flowers of the hop-plant form cone-shaped aggregations, called by botanists strobiles, and on their scales are numerous resinous spherical glands, which, when rubbed off, have the appearance of a yellow powder, in which the principal constituents are found.

The following analysis will show the composition of hops:

Scales	80 per cent.
Yellow powder	20 per cent.
	100

	Scales.	Powder.
Volatile oil	..	0·12
Bitter principle	4·7	3·0
Tannic acid	1·6	0·7
Resinous matter	2·0	2·9
Gummy "	5·8	1·3
Cellular tissue	64·0	9·0
	78·1	17·02
Aqueous extract	12·1	4·9

A glance at the above table shows that the volatile oil is contained exclusively in the powder, but it is only fair to state that other analysts have arrived at somewhat different results. The bitter principle is found in the scales as well as in the glands, but the powder contains a larger proportion. The following table gives the relative quantities of the constituents in 100 parts of scales and powder:

	Scales.	Powder.
Volatile oil	..	·71
Bitter principle	6·0	17·62
Tannic acid	2·1	4·11
Resinous matter	2·6	17·04
Gummy "	7·4	7·64
Cellular tissue	81·9	52·88
	100·0	100·00

The *Oil of Hops* is one of that large class known as volatile oils, of which oil of turpentine is the best known example; and it partakes of the qualities common to them all. It has a yellowish colour, which

darkens upon exposure to the atmosphere; it absorbs oxygen from the air, with evolution of carbonic acid, and thus forms a solid resinous matter; it has a specific gravity of 0·908, and commences to boil at 260°. When boiled with water, however, hops give off their oil at a much lower temperature, which is carried off mechanically by the steam. The resin formed by the oxidation of the oil, and that found originally in the hops, have not at present been proved to be identical, but no doubt can exist that such is the case; and the idea will at once suggest itself, that the greater part, if not the whole, of the resinous matter is formed by the gradual oxidation of the oil. The knowledge of this fact ought to cause the hop grower, the hop factor, and the brewer, to use such means as are possible to preserve the hops from the atmosphere.

The oil in hops is absorbed by the resin, from which it is most difficult to be separated; and the analysis given above shows a percentage of oil, probably lower than the actual amount, as it is next to impossible to obtain the whole of it from the resin. To obviate this difficulty, some brewers are in the habit of cutting up the hops previous to putting them in the copper, so that the resin, which is insoluble in water, may be separated, and the oil subsequently withdrawn from it.

The *Bitter Principle* of hops is contained for the most part in the scales of the flowers, although it is found also in the powder. Its chemical composition has not at present been satisfactorily determined. It is found to dissolve in water, but it is very much more soluble in alcohol. This constituent is of great im-

portance to the brewer, for upon this he depends for producing the peculiar bitter flavour which is now so much liked in beer. No chemical test is at present known which will determine the amount of this substance; the only means of determining the value of a sample of hops, as a bitter producing material, being by making an extract, and deciding by the sense of taste.

Tannic Acid must be considered to play a most important part in the operations of brewing. Hops contain this body both in the scales of the flowers, and also in the powder which covers them; but it is in the former part that the acid is for the most part found. This acid, unlike the volatile oil and bitter principle already treated of, is not confined to the hop-plant, but is also found in many others, more especially the oak, the bark of which contains a very large amount. It is easily extracted by water, being extremely soluble in that fluid, and it has a peculiar astringent taste; but its important property is that of combining with all albuminous or gelatinous bodies, and forming an insoluble and leathery compound. It is this property which causes tannic acid to be employed by the tanner, and to the brewer it is equally important, as affording a means whereby any excess of nitrogenous substance may be separated. Hops owe their preservative action more to tannic acid than to any other constituent, and it is by removing those bodies which are so prone to decomposition, that it preserves the beer. In tannic acid we have a means of disposing of those constituents of the

wort, which are known to be the real cause of the decomposition and untimely changes which so often occur subsequently in the beer. Tannic acid also serves a further purpose, namely, of clarifying the wort; for when the acid combines with the glutinous substances and precipitates them, the suspended matters are also carried down, or to the surface in the form of scum.

3. Process of Manufacture.

The process of manufacture of beer may be conveniently divided into four parts, viz. mashing or the preparation of the sweet-wort; boiling, or the preparation of the bitter-wort; cooling; and lastly fermentation.

1. Mashing, or the Preparation of the Sweet-wort.

The object of mashing is to extract from the malt all the constituent parts which are soluble in water, and at the same time to convert some of the insoluble constituents into bodies capable of being dissolved. To fully understand the changes which take place in the mash-tun, it will be necessary to have an exact knowledge of the chemical composition of malt, and for that purpose I must refer to the analysis of malt previously given. It will be seen that there are about 15 per cent. of soluble constituents, and 80 per cent. of insoluble matter; the fatty matter does not dissolve, but is miscible with water, and the inorganic matter is partially soluble. Were the brewer only to need and use those substances which exist in a soluble form in

the malt, he might confine himself to cold water, but it is his object so to change the starch that it shall become soluble. Malt contains about 2 per cent. of soluble albuminous compounds, and it is found that these exert a peculiar action upon the starch when the malt is mixed with water at a temperature varying from 155° to 170°, the starch being gradually converted into dextrine and sugar, both of which are soluble. This extraordinary change is usually ascribed to the powerful influence of the *diastase*, that mysterious substance which has never been isolated; but it seems more probable, that the conversion of starch into sugar is due to the united action of several soluble albuminous compounds, rather than to one distinct body. Be that as it may, there is in malt a substance (no doubt of an albuminous nature) which is capable of converting starch, at a temperature of 170° F., into dextrine and sugar, and it is the brewer's interest to make proper use of this.

The malt, preparatory to mashing, is crushed, in order that a large surface of the farinaceous matter may be exposed to the action of the liquor. The excise laws compel the brewer to crush the malt with smooth rollers, and not grind it, with the object of preventing him from using unmalted grain which cannot well be crushed without clogging the mill. Some diversity of opinion exists amongst brewers as to the state of fineness to which the malt ought to be reduced; if it is crushed too fine, it is very apt to ball and set, and thus portions may escape the action of the water; on the other hand, if it is coarse, the soluble

portions are not so readily extracted, and the diastase is prevented from immediately acting upon the whole of the starch, and consequently a much longer time is employed in the process of mashing.

By referring to the analysis of malt, it will be seen that 15 per cent. of its weight dissolves in water, and these constituents we may therefore dismiss for the present. No chemical change is necessary to bring about their solution, but it is the albuminous portion of these soluble constituents which converts the starch into sugar. These soluble albuminous bodies contain a small portion of this so-called diastase, and immediately that it begins to act upon the farina, it produces, at the proper temperature, dextrine and sugar, both of which dissolve in water. Sugar is not formed directly from the starch, for there is always this intermediate product, the name of which is derived from the property which it possesses of turning a polarized ray of light to the right. By the subsequent action of the diastase upon this dextrine, sugar is formed, though it has been found by experiment, that it is impossible to completely convert dextrine into sugar, the product being always a mixture of the two substances. Though the action which takes place in the mash-tun is entirely chemical, yet it is necessary to take the best mechanical means of ensuring a thorough mixture of the materials. The mash-tun in its simplest form consists of a wooden circular tub, varying in size according to the requirements of the brewery, though sometimes it is made of cast iron. It is usually fitted with a false bottom composed of iron plates, perforated

with a number of holes, upon which the ground malt or "goods," as it is called, rests; and after the operation of mashing is concluded, the wort drains away through the false bottom. In olden times the process of mashing was performed by men mixing the malt and water by means of long oars, but now a variety of complicated mechanical contrivances are brought into use for the purpose of effecting this mixture more completely. Steel's mashing machine, which is perhaps the best example, consists of a cylinder, within which revolves a shaft provided with a number of radial arms; the ground malt and liquor are admitted into the cylinder together at one end, and, passing through to be delivered into the mash-tun, are thoroughly mixed together by the action of the arms of the revolving shaft worked by a steam-engine. In addition to such a mashing machine, some breweries have the mash-tun itself provided with a revolving shaft to which a number of arms are attached; it has a double motion, one upon its axis, and the other round the mash-tun.

To give some idea of the enormous scale on which the process of mashing is conducted, I give a few particulars of the mash-tuns in some of our principal breweries. At Messrs. Truman's there are six mash-tuns, with a total capacity of 700 quarters, the three largest being capable of mashing 160 quarters each. At Messrs. Reid's there are four mash-tuns, each capable of mashing 160 quarters. At Messrs. Hoare's there are two, the larger one being capable of mashing 200 quarters. The City of London Brewery Co. have four, capable of mashing 310 quarters. At Messrs.

Mann, Crossman, and Paulin's there are five, capable of mashing 250 quarters. At Messrs. Charrington, Head and Co.'s there are three, each capable of mashing 100 quarters. At Messrs. Bass' new brewery there are seven, each capable of mashing 50 quarters, and at Messrs. Allsopp's new brewery the same.

The practical process of mashing may be summed up in a few words. The liquor is poured into the mash-tuns at a high temperature, and allowed to remain until it has conveyed a portion of its heat to the surrounding machinery, and reduced itself to the proper mashing temperature. The malt is simultaneously let in through the feeder, the machinery is put into motion, and kept in rapid work until it is thoroughly mixed. The tun is carefully covered down to keep in the heat as far as possible, and also to exclude the air, and after about a couple of hours the wort is drawn off by the tap into the underback, great care being necessary that it flows bright and clear, and that no portion of the grain be held in suspension, or allowed to flow with it. After the whole has been run off, the grain is subjected to a repetition of the same process, but allowed to remain quiescent for about half the time. If proper attention is paid to the mashing, the second wort should extract the whole of the necessary constituents, though sometimes a third mash is introduced, and the product eventually made into "table beer." The first wort, on examination in the underback, should have a white creamy head, be full flavoured, and endowed with apparent vitality and effervescence. Some brewers, instead of varied mashes of different specific gravity,

prefer extracting after the first wort, by "sparging" all the residuary matter from the grist and then amalgamating it with the first wort. The "sparger" consists of a tube perforated throughout one-half of its length on one side, and along the other half on its other side; this tube has a small cistern in its centre, which is placed on a pin in the middle of the mash-tun, so that it can revolve, on water being supplied to it, so that the whole surface of the "goods" gets thoroughly washed.

As to the temperatures to be used in mashing, much depends upon the quality of the malt, and of the kind of beer required, various mashing heats being adopted in different districts. In London the heat of the first mash is about 166°, but as the malt cools down the liquor considerably, it has in the first instance to be run in at a somewhat higher temperature. It is found that the mash retains its heat, this being due to a certain extent to the heat generated by the chemical action which takes place in the conversion of the starch into sugar. The temperature of the wort as it runs from the tap should be about 145°, but for the second mash a somewhat higher temperature is adopted.

To measure the strength of the worts, the brewer makes use of an instrument called a *Saccharometer*, of which there are several kinds in use. That of Dring and Fage is now most commonly adopted, being a brass hydrometer, with a square stem with graduations on the four sides; on the first, 1 to 20, which indicates from 1 to 20 lb. per barrel of extract according to the height at which the instrument floats in the wort; the next

side is from 20 to 40, and is used with denser worts by fixing a small brass weight to the top of the instrument; the third side is graduated from 40 to 60, and is used with a still heavier weight; and the fourth side from 60 to 80.

When all the wort has been drained away from the mash-tun, the "grains," as they are now called, are removed and sold to farmers and cowkeepers for fattening cattle.

Boiling and Hopping.—The wort is run from the mash-tun into the underback, where it is allowed to settle, and from there is pumped into the copper and boiled with the hops. The object of boiling is threefold; 1st, to coagulate certain albuminous substances, and thus remove them from the wort, as they would by their presence be prone to give rise to acidification; 2nd, if necessary, to concentrate the wort; 3rd, to extract the aromatic and bitter principle of the hops. Much difference of opinion exists amongst brewers as to the policy of boiling; one class advocates boiling to the farthest possible extreme, the other urges its entire suppression, as the real cause of the numerous acidifying trials and troubles which so often beset the brewer. To assert that boiling can be dispensed with is erroneous, as the sweet-wort contains certain albuminous compounds capable in their crude state of giving rise to immediate acidification; but when boiled, these albuminous compounds become solidified, and the very process of boiling thereby removes one of the most active acidifying agents, and consequently it is of direct importance and benefit in its result.

Whilst I grant the indispensable necessity of boiling, at the same time I do not advocate its being either excessive or long continued. When 212° F. is reached, all that is desired as far as the coagulation of the albumen is effected, and the greater the heat, and the longer it is then continued, the more likely is the wort to develop acidity; nor is the very general practice of boiling to reduce the quantity of liquid with a view of increasing the density of the wort advisable, for by proper mashing and sparging, it is practicable to obtain a wort of sufficient density for beer-producing purposes, without having recourse to long-continued boiling and evaporation.

The properties of hops in brewing are important, for in addition to medicinal qualities of a tonic character, they render the beer stimulating to the membranes of the stomach, and their active bitter principle neutralizes a peculiar sweetness in the wort which is very apt to affect the digestive organs. The three constituents—tannic acid, the bitter principle, and the volatile oil—are dissolved by the wort, whilst the resin, although not soluble in water, is extracted, and remains in the bitter-wort. The tannic acid is beneficial in separating a further quantity of the albuminous matter, with which it forms insoluble compounds, which are eventually either deposited, or thrown up as scum. Tannic acid is undoubtedly a most important constituent of hops, and in judging of their quality, steps ought always to be taken to ascertain that they contain a proper proportion of it. The bitter principle is required to give the flavour to the beer; it dissolves

with tolerable readiness, but as it is enclosed in the cells of the hop flowers, it takes some time before the wort reaches it, and therefore a somewhat lengthy infusion is required to extract the whole of it. The volatile or essential oil gives the fragrant and peculiar aroma to beer, and it should be the first care of the brewer, having selected hops which contain as much of it as possible, to transfer it to the wort, and retain it there. The essential oil evaporates to a considerable extent along with large bodies of steam. It is much changed by long exposure to the air, and becomes oxidized and converted into an insoluble resin, and for this reason old hops are not so fragrant or so strongly impregnated with it as new ones. It has been suggested that they ought to be extracted in closed vessels, and by such means a higher temperature may be used without running the risk of losing any portion of the essential oil; several patents have been taken out with this view, but up to the present time no mechanical contrivance with this object has been generally adopted in breweries with any degree of success. Some brewers do not put the whole of the hops into the copper, but reserve a portion, which are placed in a back below the copper, as a species of filter through which the wort is made to run on its passage to the cooler. This course of proceeding is very advantageous, and if the wort is run in at a proper temperature, it at once entirely absorbs the tannic acid, and no portion of the essential oil is lost or evaporated; and further, this filter of hops serves to clarify the bitter-wort.

Hops absorb and retain a considerable quantity of wort, and now it is a common practice in breweries to submit them to pressure, for which purpose a very ingenious mechanism has been invented by Mr. King, the engineer at Messrs. Truman's brewery; it consists of two series of endless chains of great strength, arranged in a wedge shape, so that a large bulk of hops enters at one end, and is compressed to a very small space before leaving the machine at the other; and in this way the whole of the wort is extracted, and the spent hops are pressed into cakes which may be used for fuel.

Cooling.—When the wort has been sufficiently boiled and the bitter and aromatic principles of the hop are thoroughly extracted, it is necessary to reduce its temperature very considerably before commencing the last and most important stage in the process of the manufacture of beer, viz. fermentation. The wort is run from the copper into a large shallow tank called the "cooler," where it remains and gradually discharges its heat into the atmosphere. Until the last few years, this was the only cooling arrangement in use in breweries, but lately there have been numerous inventions for carrying this out in a more rapid manner. These various contrivances, to which the generic term "refrigerator" has been given, enable the brewer to reduce the temperature of his worts in a fraction of the time required when only an open cooler is used; but however perfect the refrigerator may be, it is found in practice necessary to run the wort into the cooler first, so that it may deposit a quantity of albu-

minous substances, which always separate from the wort on cooling; and whilst in the cooler, many brewers resort to the use of a fan, worked by the steam-engine, which, by continually replacing the air on the surface of the wort, materially assists in the operation. Nearly every brewer has recourse to a refrigerator as well. There are endless varieties of these, but they may be divided into two classes, one of which may be designated "internal," the other "external" refrigerators. The internal are those in which the wort is run through a considerable length of piping, and is surrounded by water at as low a temperature as possible, which is removed as fast as it absorbs the heat from the wort passing through the pipes; but the great drawback is, that the wort in cooling gradually deposits a considerable quantity of matter, which eventually clogs and sometimes completely closes the pipe. Riley's is the refrigerator of this class, most commonly in use in breweries. The external refrigerators are those in which the wort runs over the outside of pipes through which cold liquid is made to run; and the kinds generally employed are Morton's, Baudelot's, and Laurence's. In some cases ice has been made use of to assist the cooling, but although the machines and apparatus lately invented considerably reduce the cost thereof, I am not aware that it has come into general use in breweries.

Fermentation.—After the wort is cooled sufficiently, it is run into the "squares" to undergo the process of fermentation: no portion of the brewer's art demands

so much attention, and is so little understood as this; and many chemical theories of the most profound nature have from time to time been promulgated, but at present we are only in the infancy of their elucidation.

The kind of fermentation which takes place in the manufacture of beer is properly designated the alcoholic. Yeast, the substance which is added to the wort to set in action the process, consists of very small microscopic balls of vegetable cells with elastic walls, filled with a liquid and a soft horny mass, which is at first attached to the walls, but extends to the middle as the cell grows. These cells multiply by gemmation, but the newly-formed ones do not separate from the central cell till they have attained to nearly the same size. In beer yeast the cells of *Torvula cerevisiæ* and of *Penicillium glaucum* may be distinguished by the aid of the microscope.

The "pitching heat," that is, the temperature at which the fermentation is started, varies considerably in different breweries; being in England from 58° to 68°, and occasionally higher; in Scotland a somewhat lower temperature is adopted; whilst on the Continent, especially in Bavaria, a temperature as low as 45° is taken. The effect of commencing the fermentation at a very low temperature is to cause a deposition of some of the resulting yeast, and therefore this system is designated as "bottom" fermentation, whilst the method usually adopted in this country is called "superficial" fermentation. One remarkable result of these two different systems is that the yeast formed during a

superficial fermentation, produces the same kind of fermentation if used with another gyle; whilst, on the other hand, the yeast formed during a "bottom" fermentation also causes a "bottom" fermentation in the next gyle. As soon as the yeast is added, a change takes place in the wort, bubbles of gas beginning to rise, and a scum being rapidly formed on the surface. These are indications of some chemical change taking place, as is further shown by the fact, that a rise of temperature ensues, and if the liquid is tested by the saccharometer, a reduction in gravity is observed. The cause of this is, that the yeast decomposes some of the sugar contained in the wort, and transforms it into alcohol and carbonic acid; this carbonic acid escaping in small bubbles gives rise to the scum, whilst all chemical action being accompanied by heat, the rise of temperature is accounted for; and as alcohol has a lower specific gravity than the sugar from which it is formed, the reason of the reduction in gravity is apparent.

In practice it is necessary that an even and regular fermentation be at once started in the gyle, as if it is only partial, the results are injurious; and with this view the yeast should be thoroughly mixed with the wort, so as to ensure the action commencing simultaneously throughout the gyle. The first result is a change in the yeast which has been added, and then an increase of it is observed; the nitrogenous substances of the wort undergo change and become insoluble, and eventually are themselves converted into yeast. According to the method adopted in most

breweries in this country, the bulk of the yeast is thrown to the surface, and, therefore, in some cases recourse is had to the process of "rousing," which consists in beating in the yeast by means of large oars, and from time to time incorporating it thoroughly with the fermenting gyle.

Superficial fermentation requires a much higher temperature than bottom fermentation, and, to initiate the process, yeast, which has been the product of a previous superficial fermentation, must be used; the change takes place so rapidly, and the resulting evolution of carbonic acid is so great, that the bubbles of gas, in rising, lift and carry up the particles of yeast and leave them on the surface in the form of scum, which, after a time, breaks up and gives the appearance of the "cauliflower head" so much admired by brewers. The wort, which ought to be tolerably bright when run from the refrigerator, becomes rapidly turbid; it rises in temperature, and to regulate the heat, coils of pipe, through which cold water passes, are often used, to which the name of "attemperators" has been given. The gravity of the wort decreases, or, as the brewer designates it, becomes attenuated, and eventually the action diminishes in intensity; this portion of the fermenting process is then stopped, the resulting yeast is skimmed off, and the beer is run into small casks to undergo the process called "cleansing."

Bottom fermentation occurs when the temperature at which "pitching" takes place is about 40°, but yeast, which has been produced by a previous bottom fer-

mentation, is also necessary. The action is much slower, and the temperature of the fermenting liquid does not rise to the same extent as by superficial fermentation; the bubbles of carbonic acid gas are much smaller, and are not sufficient to carry the yeast to the surface, and therefore it gradually accumulates at the bottom of the vat, so that this species of fermentation often requires a period of fifteen to twenty-one days to sufficiently attenuate the beer.

This latter method is the one most in use in Bavaria, where they have cellars in which the requisite low degree of temperature can be maintained; in this country there is great difficulty in reducing the temperature below 51° or 52°, as very few well waters have a lower temperature than this; while another objection which brewers in this country urge against the system, is the long period required for the process, and therefore the necessity of being supplied with much more fermenting tun room. As a matter of experience, however, it is found that beer brewed by the Bavarian method is superior in its keeping qualities. Liebig has stated that the effect of the bottom fermentation is to remove much larger quantities of nitrogenous bodies from the beer, than are removed by a superficial fermentation, and on this account, beers brewed by the former are better adapted for keeping. Chemical analysis shows that by bottom fermentation there is rather more lactic acid formed, but very little acetic acid, whilst by superficial fermentation the latter acid is formed in a larger proportion than the former.

In our large London breweries, the process of fer-

mentation is conducted on a gigantic scale; in some cases the fermenting tuns hold as much as 1500 barrels, or nearly 60,000 gallons, and the quantity of carbonic acid gas which is evolved is enormous; at Messrs. Reid's, some years since, this gas was collected and used by the Aerated Bread Company, in the manufacture of their bread, although as a rule it is allowed to escape into the atmosphere. At Burton-on-Trent, and in many other breweries after the fermentation has proceeded to a certain extent, the beer is removed into a number of smaller vats, called "union casks"; these hold from 150 to 200 gallons, and are fitted at the bung-hole with a bent pipe. After being filled with beer from the fermenting tuns, the fermentation still proceeds, and as the yeast is thrown up, it is forced through the bent pipe into a trough prepared for its reception; in this way, in course of time, the whole of the yeast is thrown off, and the beer becomes "cleansed." At Messrs. Bass's brewery, there is one room which contains about 1500 of these "union casks."

As soon as the process of cleansing is completed, the beer is fit for use; and is then racked off into casks, to suit the convenience of the consumer: usually recourse is had to finings to hasten the clarification of the beer, consisting of isinglass, or other gelatinous substances dissolved in sour beer.

4. Statistics.

As this article would not be complete without referring to the present position of the brewing trade, I propose to give some statistics, and for this purpose

shall have recourse to the Report of the Commissioners of Inland Revenue, and to Parliamentary and Agricultural Returns. A glance at the figures which follow, will give some idea of the gigantic character of this industry.

In 1874 there were 2,507,000 acres of land growing barley in the United Kingdom, and as the yield may be averaged at 20 bushels per acre, the total quantity of barley grown in the United Kingdom amounted to 50,140,000 bushels. In addition to this, we are now large importers of barley, more especially from the Baltic and Rhine provinces. In the year 1873 there were 2,587,498 quarters imported into the United Kingdom. The whole of the barley grown in and imported into this country is not used in brewing and distilling, for there is a considerable portion employed for feeding purposes, and besides we export some.

From a parliamentary return, we find that in the five years 1869–1873, the following quantities of malt have been used for consumption in the United Kingdom:

	Bushels.
1869	52,568,339
1870	56,775,614
1871	54,160,917
1872	61,608,569
1873	63,495,785

Of the above, a portion was used free of duty, for distillation or exported, leaving in 1873, 59,174,089 bushels to be charged with duty, which yielded a

revenue of 8,027,408*l*., a sum certainly large enough to frighten any Chancellor of the Exchequer from remitting the malt tax.

In the year ending March 31st, 1875, 436,991 bushels of malt were exported from this country, but as this shows a falling off from previous years, it would appear that some of the colonies are becoming better enabled to make beer from malt of their own production. In the same year, 1,367,446 bushels of malt were used in beer exported from this country, and this also shows a decrease, thus corroborating the idea that our colonies are learning to produce their own malt liquors.

In addition to malt, sugar is now largely used in manufacturing beer; in the year ending March 31st, 1875, 868,942 cwt. of sugar were used for this purpose, which quantity is equivalent to 463,436 quarters of malt; the large increase upon previous years is no doubt due to the great rise in the price of malt in 1874.

In 1873 there were about 66,000 acres planted with hops in England, of which about 43,000 acres are in the county of Kent. The hop crop is a most uncertain one, and it is therefore very difficult to estimate the produce; but in 1873 it averaged about 4 cwt. to the acre, thus giving a total growth of 264,000 cwt. On the Continent, about 76,000 acres of hops are under cultivation, and we import a considerable portion of the produce, especially from Belgium and Bavaria.

In the year ending October, 1873, the total decreased number of barrels of beer exported was 583,682,

of the value of 2,384,306*l.*; one-third of this quantity was sent to British India, and one-fifth to Australia.

In the year ending March 31, 1873, there were the following number of brewers, maltsters, and dealers in the United Kingdom, as shown by the amount paid for licences :—

	England.	Scotland.	Ireland.	United Kingdom.
Brewers	30,671	226	113	31,010
Maltsters	4,434	400	143	4,977
Malt roasters and dealers in roasted malt	24	2	8	34
Dealers and retailers of beer	123,801	1,875	18,749	144,425

The following table gives the number of brewers, and the quantity brewed in the United Kingdom, for the year ending September 30, 1873 :

Brewers Brewing. Over Barrels.	Brewers Brewing. Under Barrels.	
——	1,000	24,416
1,000	10,000	1,894
10,000	20,000	234
20,000	30,000	82
30,000	50,000	63
50,000	100,000	34
100,000	150,000	9
150,000	200,000	6
200,000	250,000	1
250,000	300,000	2
300,000	350,000	2
350,000	400,000	1
400,000	700,000	5
	Beginners	3,179
	Total	29,929

From the above statistics, we are able to form a tolerably correct estimate of the capital and number of hands employed in the malting and brewing trade of the United Kingdom. Presuming that one man is able to malt 30 bushels per day, there must be about 12,000 men engaged in the manufacture of malt. In the cultivation of the barley, taking one man to 35 acres, there are employed about 70,000 men. In the cultivation of hops, taking one man to 5 acres, there are employed about 12,000 men. In brewing, assuming that one man is required for every 500 barrels brewed, there must be employed about 135,000 men. There are 144,425 dealers and retailers of beer in the United Kingdom, and many of them employing several hands; taking into consideration all the accessory trades in connection with breweries, including engineers, coopers, &c., there cannot be far short of half a million hands employed in this important industry, and the capital invested must reach the almost fabulous sum of 200 millions. The brewing and malting trades yield to the state for duty, licences, &c., a revenue of almost 10 millions.

DISTILLING.

By T. A. Pooley, B.Sc., F.C.S.

We have no authentic records of the first manufacture of alcoholic beverages by distillation, though it is said that the use of the still was known to the Chinese at a period prior to the Christian era, but in Europe, Arnauld de Villeneuve in the thirteenth century was the first to speak of a spirit obtained by distillation of wine. We also have records that about the same period the Irish manufactured an intoxicating liquor called Usquebaugh, which is synonymous with the modern word whisky and the French Eau de Vie, aqua vitæ, or water of life. In this country the bulk of the spirit is obtained by the distillation of the fermented extracts of grain, but in France and other countries a large quantity of spirit is prepared from the fermented juice of the grape, and in Jamaica and some other parts from that of the sugar-cane. Whatever may be the source from which the spirit is derived, the process of manufacture is very similar, a saccharine extract being prepared from some grain or fruit, and submitted to fermentation by the addition of yeast; alcohol and carbonic acid being formed, similar to the action which takes place in the fermenting process in a brewery. This alcoholic fluid is then submitted to heat in a closed

vessel of such construction, that the first portions which evaporate may be collected separately, as alcohol boils at a lower temperature than water; and this distilled portion properly purified constitutes the spirits of wine of commerce.

I have lately had an opportunity of visiting one of the largest London distilleries, and I cannot do better than describe the plant, machinery, and process employed therein for manufacturing spirits of wine on a large scale.

The process is divided into two stages, viz. brewing and distilling; the former consists in manufacturing a saccharine fluid from grain, that usually employed being barley and oats, with a certain admixture of malt, which is essential to produce the requisite chemical changes in the mash tun; sometimes wheat, rice, and Indian corn or maize are used, but these are not so well adapted, as they do not undergo the transformation into sugar in the mash tun so readily as the other grain. This saccharine fluid is then submitted to fermentation by the addition of yeast, and, unlike the brewer, the distiller forces this fermentation to the uttermost extreme so as to produce as much alcohol as possible. This alcoholic fluid, technically called wash, is afterwards submitted to a process of distillation by which the spirit is separated.

I will now describe the various stages in the process of manufacture as practised in a large London distillery, and for this purpose will divide the subject into four heads, viz. grinding, mashing, fermenting, and distilling.

Grinding.—The grain passes from large granaries at the top of the building by means of hoppers into the mill-room; in the distillery referred to there are seven pairs of large French burr stones and a Hawkesley's Patent Disintegrator, worked by a 40 horse-power engine; these mills are capable of grinding about eight hundred quarters of barley and one hundred quarters of oats per week. In the operation of grinding, the meal becomes greatly heated in consequence of the friction of the stones, and as in practice it has been found that this heating is injurious to the subsequent operations, an arrangement has been contrived by means of an exhaust fan to cool the meal rapidly as it comes from the stones.

Mashing.—The crushed grain, technically called "grist," passes from the mill-room into the mash tun, where it is submitted to the action of water at a certain temperature, so as to convert the insoluble starch into soluble sugar, and thus form a saccharine fluid, known as wort. There are two mash tuns constructed of cast iron; these vessels are of enormous size, being 28 feet in diameter and 10 feet deep, and each containing about 40,000 gallons. They are fitted with movable false bottoms consisting of perforated cast-iron plates, under which are pipes to carry off the wort into the underback. Each mash tun is fitted with an elaborate mashing apparatus, consisting of a shaft which is made to revolve by a powerful steam-engine. By cog-wheel mechanism a number of horizontal and vertical arms or paddles are set in motion, the effect of which is to thoroughly stir up and incorporate the grist

with the water. The same machinery moves a kind of scraper all round the bottom of the tun, the object of which is to keep the perforations clear, as so much depends upon obtaining a complete maceration of the grist, and preventing its "balling," and therefore these elaborate mechanical arrangements are absolutely necessary. The water used in mashing is heated in three boiling backs, each holding about 40,000 gallons, by means of perforated radiating steam pipes. In consequence of the strict excise regulations under which the two operations of brewing and distilling are not allowed to be carried on simultaneously, it is usual to commence the mashing on a Wednesday and complete it by Saturday, during which time a quantity of wort is made, sufficient to fill thirteen wash backs and a wash charger, or about 320,000 gallons in all. In different distilleries various mixtures of grain are used, but in every case a certain proportion of malt is absolutely necessary, to supply the diastase or substance required to convert the amylaceous bodies into saccharine products. The Scotch distillers generally use a mixture approximating to the following:

Malt	2 parts.
Oats	1 "
Rye	1 "
Barley	7 "

In Ireland, where large quantities of home-grown barley and oats highly kiln dried are mashed, the following are the usual proportions:

Malt	2 parts.
Oats	1 "
Barley	7 "

In the London distillery previously referred to, the following are employed:

Malt	12 quarters of	336 lb.
Oats	16 ,,	304 ,,
Barley	112 ,,	400 ,,

One mashing or brewing consists of the above quantities and proportions. Water at a temperature of 140° F. is run into the mash tun from the boiling backs, allowing 66 gallons to each quarter of grist. The mashing machinery is then set in motion and the grist passes from the grinding room through shoots, and is thoroughly incorporated with the water in about an hour, when more water at temperatures ranging from 160° to 180° F. is slowly added, until the requisite quantity has been run in. As the grist soaks up a certain amount of liquid, and this quantity varies with the nature of the grain employed and the state of fineness to which it has been reduced in grinding, it is only by actual experience that the distiller can tell when sufficient has been added; the temperature of the mash should be 150° F. and the gravity about 38.

The changes which take place in the mash tun are principally the conversion of starch into sugar. In the article on brewing, the subject has already been fully discussed, and in the process of distilling the chemical actions which are brought about are very similar. Malt contains a certain proportion of soluble nitrogenous substances which possess the remarkable property of transforming starch into sugar; to these substances the name diastase has been given. The

proportion of diastase in malt does not exceed 0·002 to 0·003 per cent., but one part of diastase is sufficient for the conversion of 2000 parts of starch. It will thus be seen that only a small proportion of malt is actually required to convert the starch of a large quantity of raw grain into sugar, but in practice it has been found not advisable to reduce the proportion of malt to raw grain to less than one-tenth or one-twelfth, whilst in many distilleries a much larger proportion is used. Worts made from grist with a small proportion of malt are usually thick or cloudy, in consequence of a certain quantity of unconverted starch remaining in suspension, whilst those made from grist containing much malt run off quite bright.

After sufficient water has been run into the mash tun, the goods are allowed to rest for about 30 minutes so that they may settle. The taps underneath the mash tun are then opened, and the wort, passing through the perforated false bottom, is conveyed by pipes into the underback. After standing some time, the grains settle to the bottom and leave some of the wort quite clear on the top; this is also run off by pipes arranged for the purpose. As the wort runs into the underback, two large pumps, 12 inches in diameter, are set in motion to force it up into the wort receiver, from which it passes through the refrigerators into the fermenting squares. The refrigerating apparatus consists of eight cylinders, each containing 260 copper tubes 8 feet long, all connected alternately at top and bottom. A continual supply of cold water is pumped through the refrigerators, and in this way the wort is reduced to a

temperature of from 74° to 80° F., according to the temperature of the atmosphere. When no more wort can be run off from the mash tun, the grist or grains are mashed a second time with water at 180° F. and run off as before, and this second wort is pumped into one of the boiling backs to be used for the next mashing of fresh grist. The grains are mashed a third time with water at 196° or 200° F., and the third wort is also pumped into a boiling back to be used over again for mashing. The grains have by these three successive mashings become completely exhausted of all starch or sugar, and the only substance remaining are the husks, with some insoluble fibrous and glutinous bodies. A quantity of boiling water is next run into the mash tun and the grains thoroughly mixed with it; powerful pumps then convey this mixture of grains and water into a large receiver called the grains reservoir, where they are allowed to settle, and the water drawn off through perforated plates, the same as in the mash tun. This weak wort is run into another boiling back to be used for a fresh mashing, and the comparatively dry grains are thrown down through a large valve to the grains loft, and then loaded on to waggons and sold for cattle feeding, as they still contain much nourishment. Each mashing is like the one just described, except the one immediately preceding the distillation. As stated above, the excise regulations do not allow the two operations of brewing and distilling to be carried on simultaneously, so that no wort can be held over in the boiling backs, but must be collected into the fermenting backs; con-

sequently all wort run from the first, second, and third mashings on the last day of brewing must be conveyed into the fermenting back, before the process of distilling is allowed to be commenced.

Fermenting.—After a strong saccharine fluid has been prepared in the manner just described, and the whole of the wort has been collected in the huge fermenting backs, the process of fermentation is commenced. In the article on Brewing, the chemical actions which take place in this process have already been described; the main feature is the conversion of sugar by the influence of the yeast into alcohol and carbonic acid, represented by the following chemical equation:

$$\underset{\text{Glucose.}}{C^6H^{12}O^6} = \underset{\text{Alcohol.}}{2\,C^2H^6O} + \underset{\text{Carbonic acid.}}{2\,CO_2}.$$

There are besides, a number of secondary products such as succinic acid and glycerine, but these are detrimental to the distiller, as they represent so much waste. In the London distillery previously referred to, it is the usual practice to add $\frac{3}{4}$ to 1 per cent. of yeast to the worts at a temperature of 74° to 80° F., and push on the fermentation as rapidly as possible, so as to complete it in three and a half to four days. Some of the Scotch distillers use a larger proportion of yeast, and working at a somewhat lower temperature, the fermenting process lasts from four to five days. In the article on Brewing, the advantages accruing from the system of fermentation at low temperatures have been pointed out. The brewer desires to retain as far as possible the aroma of the hop and malt, and to

convert only a portion of the sugar into alcohol, leaving a large proportion of the sugar and dextrine remaining in the beer; the distiller on the contrary endeavours to convert the whole of the sugar into alcohol, and at the same time to avoid the formation of secondary products, and more especially the oxidation of the alcohol into acetic acid. During the process of fermentation, a considerable rise in temperature takes place, and the gravity of the wort decreases as the sugar is converted into alcohol. Donovan gives the following table, showing the gradual rise in temperature and decrease in gravity in a wort under fermentation for five days:

	Temperature. °	Specific Gravity of Wort.
First morning	70	1·050
„ evening	70	1·050
Second morning	72	1·046
„ evening	76	1·032
Third morning	80	1·022
„ evening	84	1·012
Fourth morning	88	1·007
„ evening	88	1·005
Fifth morning	88	1·003
„ evening	86	1·001

In practice it is of the utmost importance that, as soon as it is commenced, the fermentation should go on regularly until the necessary attenuation is obtained, for if from want of sufficient yeast, or too low a temperature, or other cause, the process stops, a serious loss occurs, as it is found very difficult to resuscitate the action, and as a result, a portion of the alcohol is

converted into acetic acid. As soon as the wort is attenuated sufficiently, which may be known by the froth on the surface beginning to fall, it is important to submit it as soon as possible to distillation. Practically it is not possible to convert the whole of the sugar into alcohol, for although the attenuation may sometimes be carried sufficiently far to reduce the specific gravity lower than that of water, yet a certain proportion of saccharine remains.

Distilling.—By the excise regulations distillation must not commence until four hours after all the wort has been collected in the fermenting backs, but when the brewing ends on a Saturday, as is usual, distilling does not commence until the following Monday morning.

Distillation is the conversion of a volatile substance into vapour, and arranging the apparatus in such a manner that the vapour is condensed in another vessel provided for the purpose. When a liquid contains two substances, boiling at different temperatures, the process of distillation may be used to separate them, for the one boiling at the lower temperature will of course volatilize first and may be collected in a comparative state of purity, although several distillations would probably be required to obtain this substance in absolute purity. For instance, water boils at 212° F., and alcohol boils at 173°, and a mixture of equal parts of alcohol and water boils at about 192°. If such a mixture is placed in a suitably-arranged apparatus, or retort, as it is called, and heated to 192°, it will boil, and the vapour given off, will consist for the most part of

alcohol: by arranging the apparatus in such a way, that the vapours may be cooled so as to condense into a liquid again and run into a separate vessel, called the receiver, nearly the whole of the alcohol may be separated from the water. The fermented wort or wash is a fluid containing certain proportions of alcohol and water, and it is the object of the distiller's art to separate these two substances as effectually as possible.

The common still consists of a large globular-shaped vessel usually made of copper, surrounded by brickwork; underneath is a furnace so arranged, that the flues carry the heat all round. To the top of the still is attached a large pear-shaped head, which at the summit is bent downwards so as to convey the vapours into the condensing apparatus, consisting of a long worm-like tube arranged in a large vessel containing cold water. This kind of still is in use in some small distilleries at the present time, but many important improvements have been effected in the process of distilling during the last fifty years. In the year 1799, in consequence of the great improvements made by the Scotch distillers in the construction of their stills, more especially by exposing a very large surface to the fire, the excise duty was levied according to the capacity of the still, and on the supposition that it would be worked off and charged every eight successive minutes during the distilling period. Further improvements were made, which enabled the distiller to distil off, empty, and make ready for a successive operation, a still of 80 gallons in three minutes and a half; after this the duty was levied upon *the* spirit produced, without reference to the kind of

still by which it was produced. A variety of distilling apparatus has been invented to supersede the old-fashioned still, but that which has been most successful and is mostly in use is Coffey's. In the London distillery previously referred to there is a Coffey's Patent Still capable of distilling 4200 gallons of wash per hour, that is, of producing about 400 gallons of proof spirit. This ingenious apparatus consists of two rectangular wooden boxes, called respectively the "*Analyser*" and "*Rectifier*"; the former being composed of thirty-two chambers or frames one over the other, separated by perforated copper sheets, having two valves and two dropping pipes, with pans under them, placed so that the wash must flow over each sheet before it runs down to the next. Steam is injected at the bottom, and a constant pressure of 4½ lb., or 5 lb. to the square inch prevents the wash from falling through the perforations, and at the same time exhausts it of its alcohol, which passes off in the form of vapour, although in an impure state. This impure spirit is conveyed as vapour from the highest chamber of the analyser through a pipe to the lowest chamber of the rectifier, which is a column similarly furnished with perforated sheets and dripping pipes, but, in addition, with a continuous zigzag pipe, having four lengths in each chamber. This pipe is connected with the wash-charger, a vessel into which the wash is forced from the fermenting backs by a set of powerful pumps, while another set forces the wash through the whole length of the zigzag pipe, commencing at the top of the rectifier and running through its several frames to the bottom and

from thence to the top compartment of the analyser, where the wash is thrown on the perforated copper sheets previously described. The wash is at this time boiling from the contact of the pipe, through which it is pumped with the weak and impure spirit vapour rising from the lower frames of the rectifier, which thus heats the fresh wash and loses some of its own impurities and water the higher it ascends, so that by the time it arrives at the fifth frame from the top of the column, it is generally about 66° or 67° over proof. It is then considered pure raw spirit, and is drawn off from a solid copper sheet having two large holes, with rims about 1 inch high round them, by a pipe which leads to the spirit refrigerator, which is a large tank containing a supply of cold water, through which the pipe conveying the spirit passes in a zigzag manner from top to bottom and then discharges itself into the spirit receiver. This pipe has also a branch leading through the feints refrigerator to the feints receiver, where a small residue of impure spirit and fusel oil is collected at the end of each week's distillation. Connected with the bottom of the rectifier is a hot feints receiver to collect the weak impure spirit, which is being continually condensed in the lower frames of the rectifier, and this is pumped back to the top compartment of the analyzer and redistilled with the wash.

The apparatus requires the most careful attention on the part of the man working it, who is guided by feeling the temperature of the part of the wash pipe (called the "working bend") immediately above the *spirit sheet* or frame of the rectifier from which the

pure spirit is drawn, and which must always be kept about 100° F. or good blood heat, so as barely to allow the spirit vapour to ascend above the copper sheet and be immediately condensed on it. If the pipe gets too hot, there is a possibility of fusel oil ascending and so destroying the flavour of the spirit; and if kept too cold, the spirit vapour will be condensed before it reaches the sheet, will fall down to the hot feints receiver and have to be re-distilled, involving loss of time and waste of fuel, besides risking loss of spirit by increasing the strength of the wash in the analyser. The patentee does not warrant this apparatus to exhaust any liquid containing more than 12½ per cent. of proof spirit, so that in this latter case spirit would pass away with the spent wash, which is drawn off from the bottom of the analyser through a syphon pipe to a tank, from which it is sold for pig and cattle feeding.

The different cocks, and a sampling apparatus by which the still is regulated, are on the working stage or floor where the man in charge stands, within reach of his hand, as he cannot leave that stage at any time for five minutes without danger to the working of the apparatus.

Two spirit receivers are used alternately, to enable the excise to take account of the spirit before it runs into the spirit vat, where it is reduced with distilled water to about 25° over proof, at which strength it is put into casks and sent out for consumption.

The whole of the process is under the immediate supervision of the excise officers, and as the revenue

derived from spirits is so great, every precaution is used to secure a correct gauging of the quantity manufactured; the regulations requiring that all the conduit pipes be painted *black;* those for the wash, *red;* those for the first distillate, *blue;* and those for the finished spirit, *white.*

The distillery specially referred to, and there are several such in London alone, is capable of producing between 19,000 and 20,000 gallons of proof spirit per week. As the duty is 10*s.* per gallon, this represents a revenue to the crown of about 10,000*l.* a week, or half a million a year from one establishment alone at full work. About 1000 quarters of mixed grain, that is barley, oats, and malt, are required to manufacture the above quantity of spirit. The quantity of spirits which may be produced from the different materials used by distillers depends very much on the quality of the respective materials, but Mr. Young, of the Inland Revenue, states that on an average

1 quarter	of barley malt	will yield	18	gallons	of proof spirit.
1 „	„ malt grain	„	20	„	„
1 cwt.	„ sugar	„	10	„	„
1 „	„ molasses	„	7	„	„
1 „	„ rice	„	7½	„	„
1 ton	„ beetroot	„	15	„	„

By actual practice, I find the average produce from undried foreign corn used in the following proportions,

Malt	12
Oats	16
Barley	112

to be 1 gallon of proof spirit from $20\frac{1}{4}$ lb. of the mixed grist. In an Irish distillery where only home-grown barley and oats highly kiln-dried, and one-fifth of malt are used, 1 gallon of proof spirit is produced from 18 lb. of the mixed grist; sometimes in favourable seasons, and working with high-class corn, the produce even exceeds this, $17\frac{1}{4}$ lb. mixed grist producing 1 gallon of proof spirit.

The term "proof" is used to express the strength of the spirit, and it has come into general use in consequence of the excise authorities adopting it as the standard. According to Act of Parliament proof spirit has a specific gravity of 0·923077 at 51° F., or 0·919 at 60° F., and at 51° F., 13 parts of it weigh exactly the same as 12 parts of pure water. When spirit is said to be 30 per cent. *above proof*, it means that 100 parts of this spirit and 30 parts of water will yield 130 parts of proof spirit; and when spirit is said to be 30 per cent. under proof, it means that 100 parts of this spirit contain 100 minus 30 or 70 parts of proof spirit.

It is of great practical importance both to the distiller and merchant, and also to the excise, to have a ready and simple means of testing the strength of various samples of spirit, and for this purpose the hydrometer is always used, Sykes' being the instrument usually employed. The results obtained by various experimenters have led to a table being drawn out, expressing the exact rates of pure alcohol to water in spirits of various densities, so that having taken the specific gravity with the hydrometer, the distiller can

by reference to these tables ascertain the percentage of alcohol, which any particular sample of spirit contains.

The spirit as manufactured by the process described above constitutes what is known in commerce as *plain British spirit*, and before it is fit for consumption, it is usually submitted to a process of rectification by which some volatile impurities are removed. Rectifying is carried on as a separate business, as the excise regulations will not allow this process to be carried out in the same building in which the raw spirit is manufactured. The number of manufacturers of spirit in England is comparatively small, but the rectifiers, or distillers as they are commonly called, are much more numerous; they purchase the raw spirit and re-distil it, adding certain alkaline salts for the purpose of removing the oily impurities which are always present to some extent; they then add various herbs and seeds containing volatile essential oils, and the spirit being again distilled, has imparted to it distinct flavours.

Whisky is a spirit manufactured in large quantities in Ireland and Scotland from malt; peat, or birch wood being used in drying the malt, impart a peculiar flavour, and certain empyreumatic oils distil over with the spirit, which give it a characteristic taste.

Gin is manufactured by the rectifier by adding certain proportions of juniper berries and other flavouring seeds to the spirit, which is then re-distilled: certain volatile oils distil over with the spirit and impart their peculiar flavours. *Hollands* and *Geneva* are two varieties of a similar spirit much used on the continent.

Rum is prepared in our West Indian colonies by distilling the fermented juice of the sugar-cane, and *Brandy* is made in France by distilling wines, although a variety called *British Brandy*, of very inferior quality, is manufactured in this country by distilling spirits, with the addition of some wine stone or lees, and the extract of prunes to give it a flavour.

Statistics.—In the year ending March 31st, 1875, 30,644,750 gallons of spirit were charged with duty in the United Kingdom, yielding the enormous revenue of 14,895,769*l.*, showing an increase on all previous years; of this quantity 29,821,574 gallons were retained for consumption as beverage, which gives an average of about one gallon of spirit consumed by every man, woman, and child in this country during the year. The following figures show the exact quantities consumed per head in each division of the kingdom, from which it appears the Irish consume half as much again as the English, and the Scotch three times as much.

	Quantity of Spirits consumed per head of Population.
England	0·707 gallons.
Scotland	2·018 „
Ireland	1·149 „

In 1874 we exported 1,542,252 gallons of spirit, a large portion of it being sent to Australia and other British possessions; but over 200,000 gallons were exported to Portugal, and it is reasonable to suppose that we receive back a considerable portion of this in the form of port wine.

The number of distillers and rectifiers in the United Kingdom, in 1875, appears by the number of Excise licences taken out to be as follows:

England	122
Scotland	131
Ireland	65
United Kingdom	318

The enormous number of 138,845 licences were issued in the year ending March 31st, 1875, to persons dealing in and retailing spirits.

It would be out of place to dilate here on the influence on the health, morals, and well-being of the community of so large a consumption of spirits, for nearly the whole of that manufactured is used as a beverage, only a small portion being required in other manufacturing processes; but as in all countries there are numbers of individuals who have not the strength of mind to confine their use of alcoholic drinks to a temperate, proper, and legitimate extent, by which no injurious effects are produced, so it becomes necessary for a well-organized State to put, by means of heavy duties, such restrictions on the manufacture and sale of spirits as will control the use, and to some extent prevent the abuse, whilst at the same time a large revenue is realized. In this country, heavy as the duty is, it is not sufficient to prevent the consumption of spirits increasing year by year.

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